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Aerial Command and Control of Unmanned Aircraft Systems

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14. ABSTRACT
The benefits provided by teaming unmanned aerial systems (UAS) with active in-flight crewmembers suggest research should be conducted on the practicality of this pairing. This study was conducted to examine two issues: the flight performance of a simulated UAS flight piloted within a UH-60, and the potential for motion sickness when piloting the UAS within the UH-60. UAS flight conditions consisted of a training (lecture) session, within a grounded UH-60, within a flying UH-60 with unobstructed windows, and within a flying UH-60 with obstructed windows. Being within an in-flight UH-60 resulted in little negative UAS flight controller performance, but did lead to increased motion sickness, especially during vigorous flight conditions. Results suggest that further research is necessary concerning the issue of motion sickness prior to implementing UAS operation within an in-flight UH-60.

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Introduction

Unmanned aircraft systems (UAS), formerly referred to as drones, remotely controlled vehicles (RCV), unmanned aerial vehicles (UAV) or unmanned combat aerial vehicles (UCAV), are used by several Armed Forces. They are typically controlled from a ground control station (GCS), which is located at a fixed position. The missions for UAS use are wide and ranging from reconnaissance, intelligence or identification to weapons deployment. It has become more obvious that teaming manned and unmanned aircraft could be a force multiplier and lead to enhancing mission success, thus increasing survivability of the manned team partner.

Defense expert for the Congressional Research Service, Leister (2007) stated that the UAS will soon be a part of the standard equipment for the Infantryman or Marine, in addition to the helmet, rifle, and boots. These UAS are used to accomplish “3D” missions, those that are dirty, dull or dangerous, and do not require a pilot in the aircraft’s cockpit. Depending on the mission type, the UAS can be flown automated via global positioning system (GPS) guided waypoints, or flown by a remote pilot (Goodman, 2002). Although the automated flight may benefit initial surveillance of an area, the ability to be flown by a remote pilot is useful for current information in the dynamic battlefield. This current information could be used to provide aerial surveillance or target detection for Soldiers, convoys, artillery, or aircraft, which are either within or about to enter dangerous territory.

Manned-Unmanned teaming

The benefit of Manned-Unmanned (MUM) teaming is that combining manned and unmanned systems leads to the high flexibility of having another field of view for those manned systems in the field, without having additional risks of human life loss. Bergantz, Delashaw, MacWillie, and Woodbury (2002) highlight that the biggest advantage of a manned system versus the unmanned and remotely controlled systems is that a human being is on-site, and thus able to develop an all-around greater situational awareness (SA) and obtain an overall “feeling” of the environment. Being on-site allows the controller to immediately adapt to both the anticipated and unforeseen situations that may arise, focusing on the best way to utilize the equipment. This has led researchers such as Svenmarck, Lif, Jander, and Borgvall (2005) to raise the question of where the UAS operator should be located, such as at a distant location, on the ground near the field of battle, or in a manned platform on-site. The concern is that the remoteness of a ground controller in relation to the UAS and environment is a challenge that may affect overall collaboration with the individuals on-site.

Callero (1995) stated that the Army is especially interested in the “bird dog” concept, wherein a crew of the aviation team exercises positive control over a UAS during their mission. He explains three possible integration modes: associated (UAS controlled by ground controller; supporting the mission with a pre-planned task); dedicated (UAS supports the combat aviation mission directly; control is executed through a ground-based UAS command station which communicates directly with the airborne crew); or coupled, which reflects the “bird dog” concept. This coupled mode places the UAS under the positive real time maneuver and functional control of one crewmember of a combat aviation team aircraft. Accomplishing control of the UAS directly by an aviation team, which is part of the on location battle team, permits precise integration of the UAS with mission fires, maneuvers, and real time decision making about how to best apply the UAS based on the course of mission events. Once UAS task decisions are made, they are immediately implemented and modified in real time. Flexibility and responsiveness are characteristics that are operationally attractive. Although Callero found three possible integration modes, Goodman (2002) described four levels of interaction. At level one, surveillance data is indirectly uploaded to the helicopters from a UAS GCS. Level four interaction is understood as the aircrew taking physical control of the UAS flight path from the GCS, while levels two and three fall between these two levels.

The first approach to MUM-teaming can be found in the work of Reed (1977), who conducted a study on controllers of remotely piloted vehicles onboard a flying platform. However, it would take two decades for interest to promote further research. The U.S. Air Maneuver Battle Laboratory (AMBL) began to explore the synergy of MUM-teaming in 1997 (Bergantz et al, 2002). The purpose was to determine the optimum level of control between manned and unmanned systems. The results indicate that MUM platforms are capable of achieving detection, classification, recognition, and identification at much greater ranges than either system could accomplish alone. The interest in MUM teaming with the UAS operator as a team member on board a manned aircraft led to several more studies. Kraay, Pouliot, and Wallace (1998) demonstrated UAS control in the coupled mode during an advanced simulator study. They concluded that the MUM-teaming concept has the potential to allow crews to acquire targets beyond the range of organic sensors without being exposed to additional threats. Hicks, Durbin, and Sperling (2009) further demonstrated MUM Teaming in an AH-64D flight simulator resulting in a tolerable workload and a feeling of higher SA of the mission environment for pilots.

Degree of automation

Barnes (1999) highlighted that the Army's approach of employing a Predator UAS to accomplish the "dangerous" work of identifying the enemy while a manned helicopter acts as the killer would be useful in today's combat. It is conceivable to team an Apache helicopter with a forward flying UAS that is controlled from an aft-flying Black Hawk for such missions. Similarly in combat search and rescue (CSAR) missions a UAS could help to keep the rescue helicopter out of the line of fire until the comrades in need of help are localized. During military operations in urbanized terrain, the troops could be deployed by a helicopter and be supported by a small vertical takeoff and landing unmanned aircraft system (VTOL UAS) controlled from the helicopter located outside of the danger zone. The VTOL UAS could land and be retrieved at the very same place where the helicopter picks up the troops, or continue to give aerial support to the helicopter as it returns to base. These scenarios suggest that it might be necessary to have UAS that are at least somewhat manually controlled and thus highly flexible compared to automated systems with preplanned or GPS waypoint flight paths.

When faced with the need for a highly flexible UAS, especially when used as a UCAV (implying that it carries weapons that could be air-to-air, air-to-ground or air-to-ship), Tirre (1998) found that the operator of such a system, as the Predator appears to be, is essentially a pilot of a (remote) aircraft. Both takeoff and landing are accomplished manually with a view provided by a fixed nose camera, and much of the mission is performed manually as well. The Predator UAS requires additional manual input from the pilot at the GCS. For cruising to the target area, servos which can hold airspeed and altitude at steady state are available, but most pilots prefer hands-on flying to avoid boredom and to maintain situation awareness. This preference for hands-on flying leads to a reduced usage of servos.

Typically UAS ground controllers are selected from the group of rated military (fixed wing) pilots because of their experience concerning aerodynamics, instrument flying, and tactics. Pilots in transition to UAS ground controlling duty have indicated that the absence of vestibular and “seat-of-the-pants” sensory input make flying the Predator quite a challenge, at least initially (Tirre, 1998).

Motion sickness

Reed (1977) performed a simulator study concerning UAS control from a moving platform and found interference of incompatible visual and vestibular sensations with the participant’s performance, resulting in errors and longer reaction times. Even in ground-based UAS control stations, incongruence between the visually perceived movement (through the nose camera view) and the “missing” vestibular stimuli can easily lead to spatial disorientation (SD). Bles (2004) stated that many UAS have been lost because of the operator’s SD with respect to the flight path of the UAS. Supporting evidence suggests that over 50% of UAS mishaps had human factor elements (Tvarynas, Thompson, and Constable, 2005), and that human factors encompass the highest percentage (67%) of causes in Predator accidents (Williams, 2004). Olson, DeLauer, and Fale (2006) performed a preliminary simulator study to evaluate if platform motion affects the UAS controller if located within a flying aircraft. To simulate aircraft movement they used a general aviation trainer (GAT II) with motion in roll, pitch, and yaw. They found some trends of deteriorated performance and observed the need for a further study, using an airborne platform instead of a simulator.

Antonov, Domogala, and Olson (2007) retested their simulator conditions in a real aircraft (Cessna 172) and found definite trends towards larger error when the control platform was moving. They concluded that their findings support a theory which states that the conflicting information between the platform motion cues and the UAS control task result in interferences that lead to decreased flight capabilities. Many of their participants mentioned that the outside visual cues created considerable difficulties and the researchers concluded that the presence of visual cues might exacerbate control errors even though those reports did not result in negative flight performance data of the participants. Their conclusion is supported by the findings of Mills and Griffin (2000), who report that visual inputs provided by the cabin, in which the participant is traveling, led to a slightly higher level of nauseogenic score than having no visual input. Ehrenfried et al. (2003) concluded that passive viewing of a moving visual field (as the visually outside world of a moving helicopter would appear for passengers and non-pilot crewmembers) interferes with cognitive tasks possibly because the threat of disorientation diverts attentional resources. When Antonov et al. (2007) presented their second study, they suggested larger studies (i.e., $N > 15$) assessing motion sickness as part of a study concerning aerial command and control of UAS.

As mentioned above, pilots or operators of UAS experience visual motion cues on their controlling screens without corresponding vestibular inputs (Tirre, 1998), which can lead to a state of discomfort. Leibowitz (1988) explained that visual-vestibular mismatch could lead to motion sickness and to spatial disorientation. Referring to simulator sickness, he described that this manifestation of motion sickness especially occurs in simulators, where the visual contours accurately represent those which are normally encountered in actual flight, but the vestibular cues are absent. Sharma (1997) also stated that motion sickness is the “response of the organism to discordant motion cues,” while Takahashi, Ogata, and Miura (1995) describe motion sickness as more of an alarm against the loss of spatial orientation. Following this loss of spatial orientation, ataxia progresses towards a dangerous level unless uncomfortable symptoms appear.

The cardinal signs of airsickness, as another manifestation of motion sickness, are pallor and/or flushing in the facial area, cold sweating, and vomiting or retching while the primary symptom is nausea, which seems to be the central mechanism behind vomiting. Cheung (2000) found that motion sickness also led to decreased performances of arithmetic computation, ability to estimate time, eye-hand coordination, spontaneity, and activity, as well as increases for participants being quiet and subdued in their behavior. The researcher concluded that the loss of well being is at least causing distraction from original tasks, which could easily result in poor flight performance. Even if the performance is found to vary independently from reported symptoms, it is necessary to see these findings in combination with the fact that aircrew distraction was thought to play a part in 44% of SD accidents among helicopter pilots (Braithwaite et al., 1997). It seems appropriate to conclude that motion sickness, distraction, and spatial disorientation as one conglomerate could potentially be a cause for accidents, incidents and mishaps that piloting a remotely controlled aircraft has in common with piloting a regular aircraft.

Facing the idea of having UAS operators on board a flying platform, Bles (2004) investigated whether incongruent motion sensations (the visual motion detected on the screen vs. felt self-motion inside the airborne aircraft) interfere with the task of controlling a UAS and/or orientation tasks involving the UAS’s orientation compared to the orientation of the operational platform. Several studies have shown that military aircrews, with the exception of pilots and co-pilots, are more susceptible to airsickness (Geeze & Pierson, 1986, Strongin & Charlton, 1991). This suggests that a UAS controller may be more likely to suffer from motion sickness if located in an airborne platform where vestibular stimuli may be in conflict with the visual information of the flight path. Additionally, Turner, Griffin, and Holland (2000) report that airsickness varies as a function of crew position with aft-facing flyers reporting sickness more frequently than forward-facing flyers, suggesting that the seating position of the UAS controller may increase or decrease overall nausea symptoms.

Objectives

The advantages of MUM teaming are numerous, but the practicality for a UAS controller to be positioned within an operational helicopter has not been tested yet. This study will address a few important issues with task performance of UAS controllers while they are located on board a flying helicopter. The main variable of interest is the perceived movement of the helicopter, which typically is not compatible with the movement of the controlled UAS. Furthermore we will examine the differences in the quality of task performance and arising motion sickness under two conditions, between being able to see the outside world’s relative movement and not being able to see the outside world’s relative movement due to covered windows. Of additional interest is whether differences existed in the quality of task performance between the orientations of the three possible seating positions that exist in the UH-60 seating area, namely backward facing, forward facing, and side facing.

Method

Participants

A total of 56 individuals were recruited for this study with 47 participating in the complete study.[1] The study had 8 additional recruits as backups in case any participants were unable to attend the study for any reason. However, none of the backups were utilized for the study. All participants were males who were enrolled in the warrant officers training course at Fort Rucker Alabama, within the ages of 19-39 years of age (mean age 25.8 years, SD ± 3.28, with a minimum age of 20, and a maximum age of 33), with less than 30 hours of flight experience as a crewmember (mean flight experience 4.13 hrs, SD ± 6.42 with a minimum of 0 hrs, and a maximum of 23 hrs). Participants were also screened for a history of motion sickness via the Motion History Questionnaire (MHQ). If they had a history of symptoms of severe motion sickness, then they were excluded from the study. Of our 47 participants, 27 reported that they were not at all susceptible to motion sickness, 19 reported they were minimally susceptible to motion sickness, and 1 reported moderate susceptibility to motion sickness. None of our study participants reported being either very or extremely susceptible to motion sickness.

Data collection instruments

Pre-study questionnaire

The pre-study questionnaire (appendix A) was designed to screen participants on their previous flight experience and their current military rank and status as well as medication status. The information obtained from this questionnaire is not discussed in the results section of this paper since the information provided in the questionnaire was used for screening purposes only.

Motion History Questionnaire

Developed by Kennedy and Graybiel (1965), the MHQ (appendix B) is a self reported history of the participant concerning their experiences in motion sickness inducing environments and any symptoms of motion sickness they experienced during these situations. The perceived susceptibility score, ranging from 0 to 15, was used for this study, with higher values associated to higher susceptibility to motion sickness (Kennedy et al., 2001).

Motion Sickness Questionnaire

The MSQ (Kellogg, Kennedy, & Graybiel, 1965; appendix C) is a self report of the participants' current symptoms of perceived motion sickness consisting of 28 items with four levels of severity. Four scores are calculated from the MSQ: nausea, oculomotor, disorientation,

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[1] A total of 48 participants was to be used in the study however one participant was initially included that did not meet the requirements for participation in the study (the individual had exceeded 30 hours of flight time as a crew member).

and the total perceived motion sickness. Higher scores indicate more severe perceived motion sickness symptoms.

NASA Task Load Index

The NASA Task Load Index (Hart & Staveland, 1988; appendix D) measures the perceived workload required for a given task. Six different workload requirements for one task are reported by the individual on a visual analogue scale with low scores indicating low task workload and high scores indicating a high demand of workload for the task.

Subjective Stress Rating Scale

The Subjective Stress Rating Scale (SSRS, Perala & Sterling, 2006; appendix E) measures both physical and mental stress. The scale includes two questions, in which the participant indicates their rating of a specific task. Low scores represent low levels of stress, while high scores represent high levels of stress.

Post-flight questionnaire

The post-flight questionnaire (appendix F) was created to determine the eating and drinking behaviors of the participants prior to their flight, along with allowing the participants to objectively rate their enjoyment and the amount of distraction they experienced during each condition. Results of this questionnaire were not statistically analyzed, but are reported in descriptive format in the results section.

Post-study questionnaire

The post-study questionnaire (appendix G) was designed to allow the participants to rate the study, their experience in the study, and to give the experimenters feedback on any useful information after contributing to the study. This survey was given only one time, 30 minutes after the final flight.

UAS flight simulator equipment

The operation of the simulated UAS flight was conducted on a Dell Latitude D830 laptop computer with a 2.4Ghz Intel Core 2 Duo CPU T8300 processor and 3.5 GB RAM, with visual settings at 1280 by 800 pixels on the highest (32 bit) color setting (an NVIDIA Quadro NVS 140M video card was used). The computer used Microsoft Flight Simulator X, with a modified Cessna 172 as the plane model for the simulated UAS flight.[2] A Logitech Extreme 3D Pro joystick was used with only the throttle lever and X and Y axes of the controller active, with all other functions turned off. This allowed for the pilot to control thrust, pitch, and roll only. The yaw movement was synchronized to the roll movement by the flight simulator software. The computer and joystick were affixed to a wooden board with foam padding on the bottom, and rested on the participant’s legs while they were seated during the study. In-house developed

[2] Participants were told they were flying a UAS, but did briefly view the Cessna 172 early in their climbing stage of the flight. The modification made to the Cessna 172 was an increase in thrust of the aircraft to simulate a smaller UAS, which also made the aircraft easier to fly.

software was used to record vital information from the Microsoft Flight Simulator X that was later used to determine flight performance.[3]

U.S. Army JUH-60 Black Hawk helicopter

The USAARL JUH-60A Black Hawk Research Helicopter (figure 1) was used in this study. The aircraft, specially equipped as a research platform, was piloted by the same two research pilots for every flight profile minimizing variations between participant flight experiences. Every flight consisted of eight participants, one research psychologist, two research technicians, and one medic. All of the non-participants were trained for the study and able to assist any participants with questions and technical difficulties during the flight.

Figure 1. USAARL JUH-60A Black Hawk.

Procedure and design

Consent

Participants were required to attend a meeting in a community conference room on the Monday or Tuesday one week prior to the flight portion of the experiment for consenting. At each consenting meeting, 28 participants were briefed about the study and then were asked to give their consent.[4] After obtaining their consent, individuals filled out the pre-study questionnaire and MHQ to screen for any previous episodes of motion sickness.

[3] The software recorded the bank, pitch, altitude, indicated air speed, feet per minute (climb rate), needle, slope, and the magnetic heading of the simulated UAS.

[4] Although 28 participants were briefed for each week, only 24 participants were used for the helicopter flights. The extra 4 participants were recruited and required to attend the training as a backup in case any individuals were unable to attend the experiment. Since all participants showed up for the study, the backups were randomly assigned and excused from the study.

General schedule

Participants were required to come in for one day to attend a training session that would take two hours and was offered both in the morning (from 9:00 to 11:00) and afternoon (from 13:00 to 15:00) on Wednesday, Thursday, or Friday of the week they consented. The following week, participants were scheduled to experience each helicopter condition on a separate day from Monday to Wednesday. Each day participants were required to arrive at USAARL at 8:00, at which time they were reminded of when their flight would take place. Pad condition activities started at 9:00, unobstructed view condition activities started at 10:30, and obstructed view conditions started at 12:30. Besides the different start times, each helicopter condition followed the same pattern of tasks and duties. Figure 2 provides a visual timeline of the tasks, and the tasks themselves will be described in more detail later in the report.

Time	Training	Pad Condition	Unobstructed View Condition	Obstructed View Condition
8:00		Report to USAARL	Report to USAARL	Report to USAARL
8:30			Lounge Time	Lounge Time
9:00	Morning Training Session Time	Baseline MSQ		
9:15		Board Helicopter		
9:30		Simulated UAS Flight 1, MSQ		
10:00		Simulated UAS Flight 2, MSQ		
10:30	Simulated UAS Baseline Flight	Post Flight MSQs	Baseline MSQ	
10:45			Board Helicopter	
11:00		Doctor Released	Simulated UAS Flight 1, MSQ	
11:30			Simulated UAS Flight 2, MSQ	Lunch
12:00			Post Flight MSQs	
12:30			Doctor Released	Baseline MSQ
12:45				Board Helicopter
13:00	Afternoon Training Session Time			Simulated UAS Flight 1, MSQ
13:30				Simulated UAS Flight 2, MSQ
14:00				Post Flight MSQs
14:30	Simulated UAS Baseline Flight			Doctor Released

Figure 2. General schedule of the experiment.

Training

Training was given to no more than eight participants at one time in the same community conference room where the consent was given. The session lasted 2 hours and was conducted at either 09:00 or 13:00 each training day. The first 80 minutes of the training was devoted to instructing the participants on the task. This included teaching the participants about the equipment they were using (flight simulator and joystick), instruction of the main tasks of the simulated flight (defined below), allowing the participants to practice the individual tasks of the simulated flight, and to allow two complete practice simulated flights similar to the main task. Following the instrumentation training a short break was given. After the break, participants filled out the MSQ. Participants then completed a full simulated and scored performance (baseline) of the same simulated UAS mission they would execute within the helicopter. With baseline flights completed, participants completed the MSQ questionnaire and the NASA Task Load Index questionnaire. This finished the training portion of the experiment.

<u>Flight details</u>

Helicopter flight conditions

The second week of the experiment involved two simulated UAS missions within the JUH-60 Black Hawk helicopter, per day, for each participant. Each day, of the second week, consisted of three flights that took place at a predetermined time. The 09:30 flight of the helicopter was the pad condition, which involved flying the simulated UAS mission twice within the helicopter with its blades running, but having never lifted off. The 10:45 flight involved flying the simulated UAS mission twice within the helicopter with an unobstructed view of the outside world. The first simulated flight of the UAS was conducted during smooth flight, while the second simulated UAS mission was conducted during vigorous flight (the flight details are discussed below). The 13:00 flight was exactly the same as the 10:45 flight, except for an obstruction of the windows, where black curtains were used to cover the windows so that the outside world was not viewable. After three days of data collection, per week, each participant had attended all three of the helicopter flight conditions in randomly assigned sequences.

Seating and flight assignment

Participants were assigned to one of six groups and to one seat within the helicopter (figure 3), in which they sat for all flights. The seats were either a gunner seat which faced the side of the aircraft, a second row forward facing seat, a third row backward facing seat, or a fourth row forward facing seat. Groups were established to provide counterbalancing for the order in which all participants completed the test conditions. On each of the three days, participants were in a different test condition.

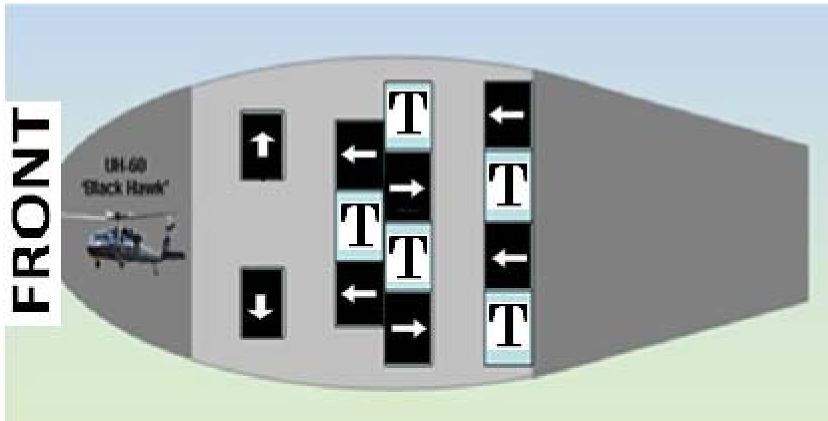

Figure 3. Seating chart for one flight. Participants always sat in the same seat (arrowed seats indicating direction they were facing) for each condition within the helicopter. The other seats represent where technicians (T) were seated.

Helicopter flight details

The smooth flight condition consisted of flying a "figure 8" flight path which never exceeded 10-12 knots of indicated airspeed (KIAS) and consisted of turns no greater than 10° of banking angle. Altitude varied slightly between 50 feet (ft) above ground level (AGL) to 100 ft AGL. Smooth flights were conducted with minimum vibration and closely simulated Nap of the Earth (NOE) flying, which is typically utilized during recon missions in helicopters.

The vigorous flight condition also utilized a "figure 8" pattern but on a larger scale. During vigorous flights, airspeeds were flown between 80 and 100 KIAS, and turns were between 10° and 30° of banking angle. Occasionally though max bank angles approached 45° during turns, which produced 1.5 to 2 G's which were experienced by the participants within the helicopter. Flight altitudes ranged from 100 ft AGL to 300 ft AGL. Vigorous flights closely simulated "contour" flight techniques, which constantly vary altitude and airspeed while following the terrain contours. To assure consistency within the vigorous flights, a flight track that followed a familiar river bed was used with clearly defined standard waypoints to indicate when turns should be initiated. During both smooth and vigorous flight regimes the helicopter was in constant motion.

Simulated UAS missions

The same simulated UAS mission was used for the training and all helicopter conditions of the study. Participants were required to takeoff from an altitude of 1707 ft and establish and maintain a climb of 700 ft per minute (fpm), while maintaining a heading of due west (the direction they initially began their takeoff maneuver). Upon reaching an altitude of 3300 ft, participants began leveling off to an altitude of 3500 ft, while still maintaining a heading of due west. At this point (and at all other times the participant was maintaining level flight) the participant was to scan their screen for anything of interest for reconnaissance purposes and to take screen shots by pressing the 'V' key.[5] Four minutes after participants were told to takeoff, they were verbally instructed to turn left to the south. During this and all remaining turns, participants were instructed to turn 90° from one cardinal direction (North, South, East, and West) to another, turning at a bank angle of 30° while maintaining an altitude of 3500 ft. Once a turn was completed, participants maintained the instructed heading and altitude of 3500 ft, while scanning the screen for targets of interest for intelligence and taking screen shots of these targets of interest. Every 1 minute and 30 seconds after their first turn, participants were instructed to turn a new direction (after turning south, they turned right to west, left to south, right to west, left to south, left to east, then right to south). A total of seven turns and eight level flights were conducted during the simulated UAS flight. One minute and 20 seconds after their last turn, participants were instructed to pause the program and end their flight. During the entire flight, participants maintained a speed within 80 to 120 knots, preferably as close to 100 knots as possible.[6]

Questionnaire and simulated UAS mission procedure of the study

Approximately 10 minutes prior to entering the helicopter, participants filled out an MSQ to determine if they were experiencing any preflight symptoms of motion sickness. Once entering the helicopter, the first 5 minutes consisted of flying the helicopter out to the starting point for the conditions where the helicopter was in-flight, after this, all conditions followed the same order. The next 15 minutes consisted of the first simulated UAS flight (smooth flight during flying conditions). Following the initial simulated flight, the helicopter hovered while participants spent the following 3 minutes completing the MSQ and NASA Task Load Index questionnaire. Once all participants were finished with their questionnaires, the next 15 minutes consisted of the second simulated UAS mission (vigorous flight during flying conditions), and followed again by 3 minutes for filling out the MSQ and NASA Task Load Index Questionnaire. After the completion of the questionnaires, the participants were flown back to the landing pad and brought inside the main building. At 5, 15, and 30 minutes after departing the helicopter, participants were given the MSQ to establish if they were still feeling symptoms of motion sickness. Additionally, 5 minutes after flight time, participants also filled out the post-flight and Subjective Stress Rating Scale questionnaires. Following the third and final flight, participants filled out the post-study questionnaire 30 minutes after departing from the helicopter.

Results and discussion

Motion sickness surveys

Motion History Questionnaire

The MHQ survey was given once during the consenting period of the study. As mentioned in the methods section, the participants had relatively little flight experience (a mean flight

[5] This scanning for targets of interest on the simulated flight was included to maintain the attention of the simulated UAS operator on the computer screen at all times and to prevent participants from concentrating on the UAS instruments solely. This would be a similar requirement to that of a real UAS operator. No true targets of interest existed in the program.
[6] All pilots were able to maintain the required range of speed and thus no data analysis was conducted on speed maintenance.

experience of 4.13 hrs, SD ± 6.42). In addition to the population descriptive information presented in the methods section, the participants also reported an overall average of 1.47 hrs (SD ± 4.33) experience in a flight simulator, with a minimum of 0 hrs, and a maximum of 24 hrs. Overall, the participants in this study had a low amount of flight experience as crewmembers.

When asked how often the participants experienced motion sickness while traveling in an aircraft, 38 reported that they had never experienced motion sickness in an aircraft, while nine reported that they rarely experienced it. Only three participants reported having ever experienced motion sickness in any situation besides air or sea sick. One participant reported he previously experienced motion sickness from reading in a car, another reported he experienced motion sickness while on an amusement ride, and a third participant, did not state the condition in which he experienced motion sickness. When the participants were asked how likely they would get motion sick in a study, which resulted in motion sickness for 50% of the participants, three reported they probably would, 33 reported they probably would not, and 8 reported that they certainly would not. Overall, the participants in this study had a very low self-reported susceptibility for motion sickness.

A one-way between subjects Analysis of Variance (ANOVA) was conducted on the Perceived Susceptibility score dependent upon their seating conditions for the helicopter flights. The ANOVA results revealed no significant differences between the groups for the seating conditions ($p = .813$). The scores for forward, side, and backward facing participants was 6.54 (SD ± 1.53, $n = 24$), 6.75 (SD ± 1.86, $n = 12$) and 6.27 (SD ± 2.15, $n = 11$), respectively. The results indicated that no initial significant differences in perceived susceptibility for motion sickness existed between the seat groupings of the participants.

Motion Sickness Questionnaire

The MSQ was given once at the start of each day each day prior to the first simulated UAS mission (baseline scores for each day), and once initially after each simulated UAS mission (a total of seven post-flight scores).[7] One participant however missed a day of the study and thus results for this test (along with other tests) were conducted with 46 participants.

Two separate ANOVAs were used to analyze the data, both using baseline adjusted scores. The first analysis was a 4 (test condition) X 3 (seat position) mixed measures ANOVA and was conducted on the four different MSQ scores. The four test conditions (within subjects) were in conference room (training), average of two flights on pad, average of two flights in unobstructed helicopter, and average of two flights in obstructed helicopter. The three seating positions (between subjects) were forward, side, and backward facing (figure 4). The ANOVAs revealed significant differences within the flight conditions for nausea scores [$F(1.911, 82.19) = 14.79$, $p < 0.001$, Greenhouse-Geisser corrected], oculomotor scores [$F(1.889, 81.24) = 9.548$, $p < 0.001$, Greenhouse-Geisser corrected], disorientation scores [$F(1.948, 83.755) = 11.781$, $p < 0.001$, Greenhouse-Geisser corrected] and total scores [$F(1.777, 76.411) = 14.387$, $p < 0.001$, Greenhouse-Geisser corrected], but no significant differences existed between seating positions

[7] The MSQ was also given to the participants at 5, 15, and 30 minutes following their exit from the helicopter. The data from all three surveys were used solely by the study physician for the purpose of medically releasing the participant from the experiment.

(p = 0.687, p = 0.559, p = 0.319, p = 0.562, respectively for the four MSQ scales) or in interactions between flight conditions and seating positions (p = 0.598, p = 0.559, p = 0.257, p = 0.577, respectively for the four MSQ scales). Post-hoc Bonferroni corrected pairwise comparisons were conducted for the flight conditions and showed that participants had significantly lower MSQ scores for both the conference room and pad conditions than the unobstructed and obstructed flights for all measurements. See appendix H, table H-1 for all significance results.

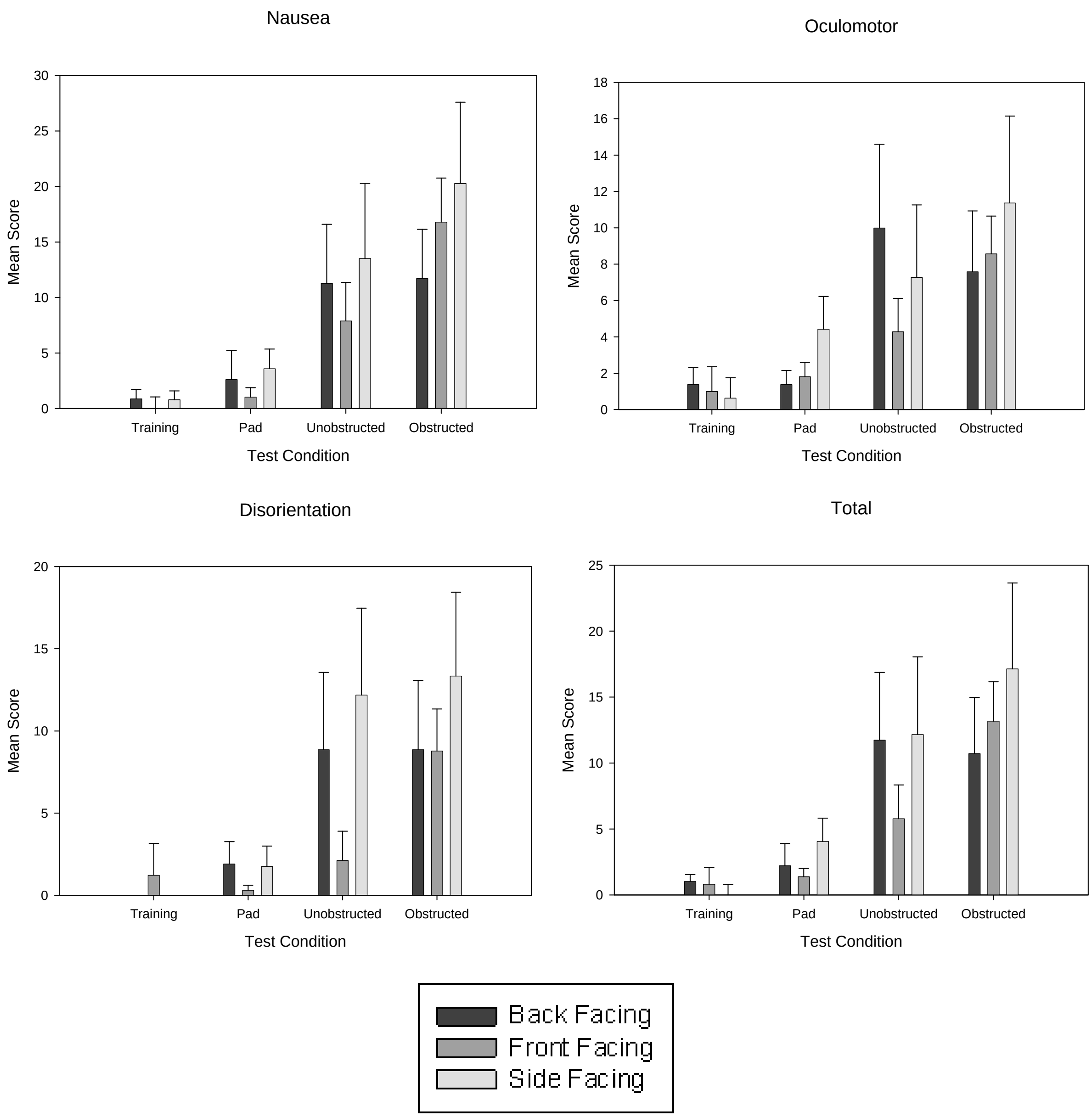

Figure 4. MSQ mean scores for each measurement by test condition. The error bars represent standard errors of the means.

The second analysis was a 2 (flight condition) X 2(flight mode) X 3 (seat position) mixed measures ANOVA, conducted on the four different MSQ scores. The two flight conditions (within subjects) were unobstructed and obstructed flights, the two flight modes (within subjects) were smooth and vigorous flights, and the three seating positions (between subjects) were forward, side, and backward facing (figure 5). Nausea scores revealed a main effect for flight condition [$F(1, 43) = 4.183$, $p = 0.047$] and flight mode [$F(1, 43) = 27.317$, $p < 0.001$], but not seating position ($p = 0.709$). While the interaction for flight condition and flight mode approached significance for nausea scores ($p = 0.054$), no interactions were significant. A main effect for flight mode was revealed in oculomotor scores [$F(1, 43) = 16.912$, $p < 0.001$], but not for flight condition ($p = 0.170$) or seating position ($p = 0.724$). A significant interaction was found for flight mode and flight condition in oculomotor scores [$F(1, 43) = 7.013$, $p = 0.011$] while all other interactions were not significant. For disorientation scores, a main effect was found for flight mode [$F(1, 43) = 16.607$, $p < 0.001$], but neither flight condition ($p = 0.13$) nor seating position ($p = 0.276$) led to significantly different scores. Despite the near significant difference in the interaction of flight condition and flight mode ($p = 0.055$), disorientation scores revealed no significant interactions. Total scores revealed a significant difference in-flight mode [$F(1, 43) = 22.964$, $p < 0.001$], but not for flight condition ($p = 0.057$) or seat position ($p = 0.632$). The interaction of flight condition and flight mode did lead to significant differences [$F(1, 43) = 6.317$, $p = 0.016$] while no other interactions were significantly different. All significant tests indicated that individuals scored higher MSQ scores when in vigorous flight than in smooth flight. The only significantly different nausea scores were influenced by an ability to view the outside world, with higher nausea scores reported in obstructed view than in unobstructed view. For total scores, an interaction between flight condition and flight mode was indicated. Bonferroni corrected pairwise comparisons were conducted and significant differences emerged between the unobstructed smooth flight with both the unobstructed vigorous flight ($p = 0.006$) and the obstructed vigorous flight ($p < 0.005$), and between the obstructed smooth flight and the obstructed vigorous flight ($p < 0.005$), with individuals demonstrating higher motion sickness in vigorous flight conditions as opposed to smooth flight conditions for these comparisons. Additionally, both unobstructed vigorous flight and obstructed smooth flight ($p = 0.054$) and unobstructed vigorous flight and obstructed vigorous flight ($p = 0.066$) conditions approached significance, while the remaining condition (unobstructed smooth flight and obstructed smooth flight, $p = 1.000$) was not significantly different. See appendix H, table H-2 for all significance results.

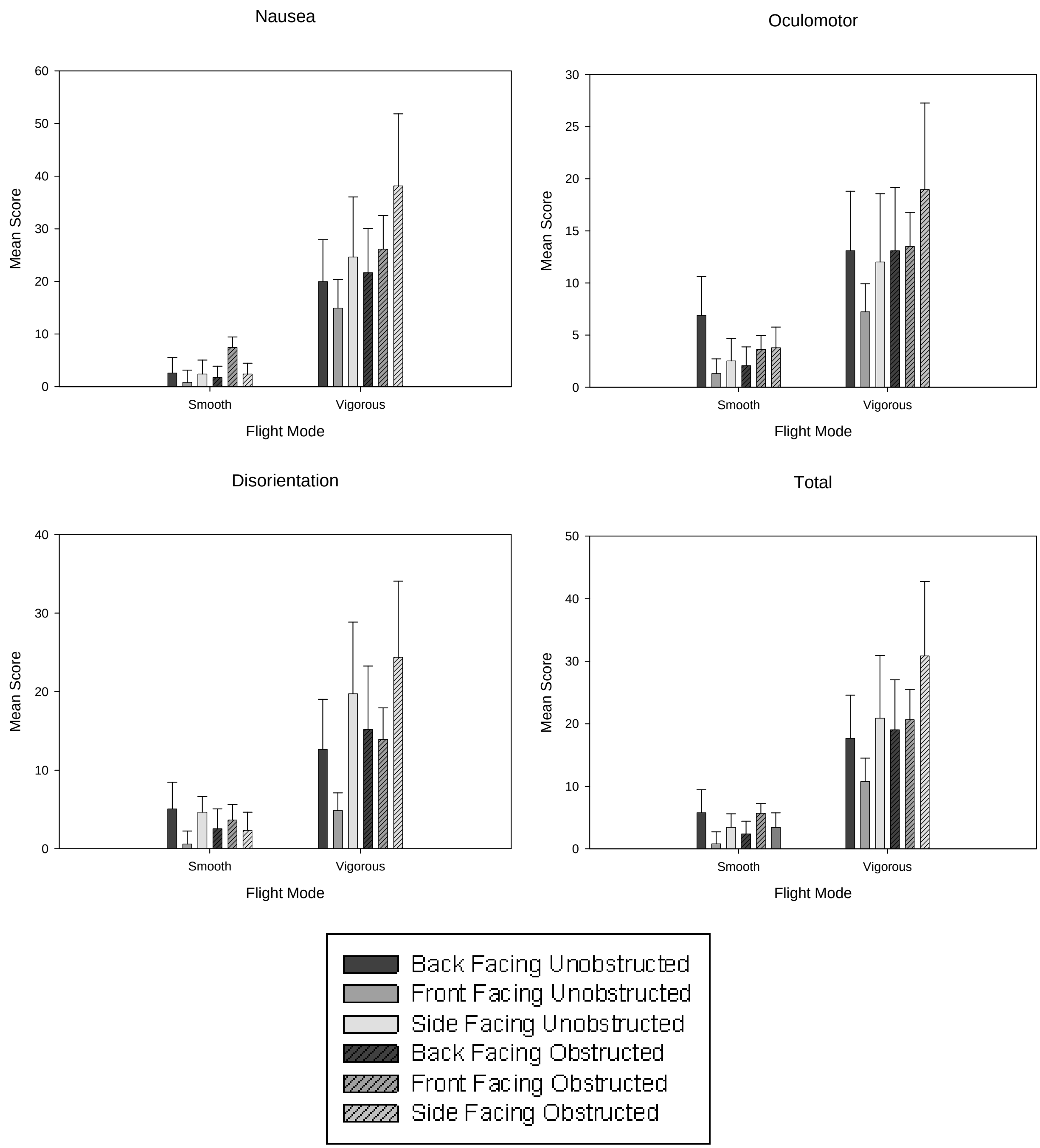

Figure 5. MSQ mean scores for each measurement by flight mode. The error bars represent standard errors of the means.

The results of this study suggest that operating a simulated UAS, while in-flight, induces motion sickness for the UAS operators. Participants reported significantly higher MSQ scores for all measurements of motion sickness when airborne as opposed to being fixed in a ground position, with no significant difference attributed to being within the conference room or inside a stationary operating helicopter. The elevated scores suggest that the added vestibular information from the flight of the helicopter interferes with the visual information the UAS operator receives from the UAS flight. Since our population reported low susceptibility to motion sickness symptoms, this could be a serious threat to MUM operations. Further research on counteracting this problem should be considered prior to serious MUM attempted operations.

In addition to the motion sickness induced by operating a simulated UAS while located within a flying helicopter, other factors concerning the environment within the helicopter play a role in experiencing motion sickness. For all MSQ scores, the vigorous flight condition led to increased motion sickness, while nausea scores were higher for obstructed viewing conditions. The results suggest that operating a UAS within accelerated flight of an aircraft would be difficult. The added vestibular feedback is most likely contributing to the nausea scores of the UAS operators, giving a very strong indication of motion that when mismatching the screen provided by the UAS flight, leads to an overriding feeling of nausea for many individuals. An increase in oculomotor scores as revealed in the interactions of flight mode and test conditions, with increased oculomotor scores during the pairing of vigorous flight with unobstructed view further demonstrates UAS operators' susceptibility toward motion sickness during vigorous conditions.

Of additional interest are the individuals who vomited during the study. As expected, no individuals vomited during the training and pad condition flights, however, a total of three participants vomited during the unobstructed flights (one individual vomited twice), while five participants vomited during the obstructed flights. All vomiting occurred during vigorous flights only.

The lack of any effects attributed to the seating position suggests that motion sickness scores were not influenced by overall orientation of the mismatch of vestibular and visual motion cues. It would appear that facing forward would lead to the least mismatch in motion cues, since a majority of the time the simulated UAS flight was moving forward and the actual flight of the helicopter is in a forward flight movement, but no advantage was found for this orientation in our study.

Task load surveys

NASA Task Load Index

Following each UAS simulated flight participants were required to complete a NASA Task Load Index survey. The analysis for this survey was conducted in the same manner as the MSQ survey, with one individual omitted due to missing a flight. The only difference from the MSQ scores was that the NASA Task Load Index scores were not baseline adjusted.

The first analysis was a 4 (test condition) X 3 (seat position) mixed measures ANOVA, conducted on the six different measurements of the NASA Task Load Index. The four test conditions (within subjects) were conference room (training), average of two flights on pad, average of two flights on unobstructed helicopter, average of two flights in obstructed helicopter and the three seating positions (between subjects) were forward, side, and backward facing (figure 6). The ANOVAs revealed a main effect of test condition for: mental task load [$F(2.056, 88.418) = 6.018$, $p = 0.003$, Greenhouse-Geisser corrected], physical task load [$F(1.843, 79.246) = 14.597$, $p < 0.001$, Greenhouse-Geisser corrected], temporal task load [$F(2.401, 103.26) =$

5.291, $p = 0.004$, Greenhouse-Geisser corrected], effort task load [$F(2.385, 102.549) = 6.614$, $p = 0.001$, Greenhouse-Geisser corrected], but not for frustration task load ($p = 0.077$). None of the measurements demonstrated a main effect of seating position or an interaction between test condition and seating position. Post-hoc Bonferroni corrected pairwise comparisons were conducted for all significantly different conditions. When significantly different, participants indicated lower task loads for the grounded conditions (training and pad) than for the test conditions (unobstructed and obstructed), and better performance for the grounded conditions than for the obstructed condition. See appendix H, table H-3 for all significance results.

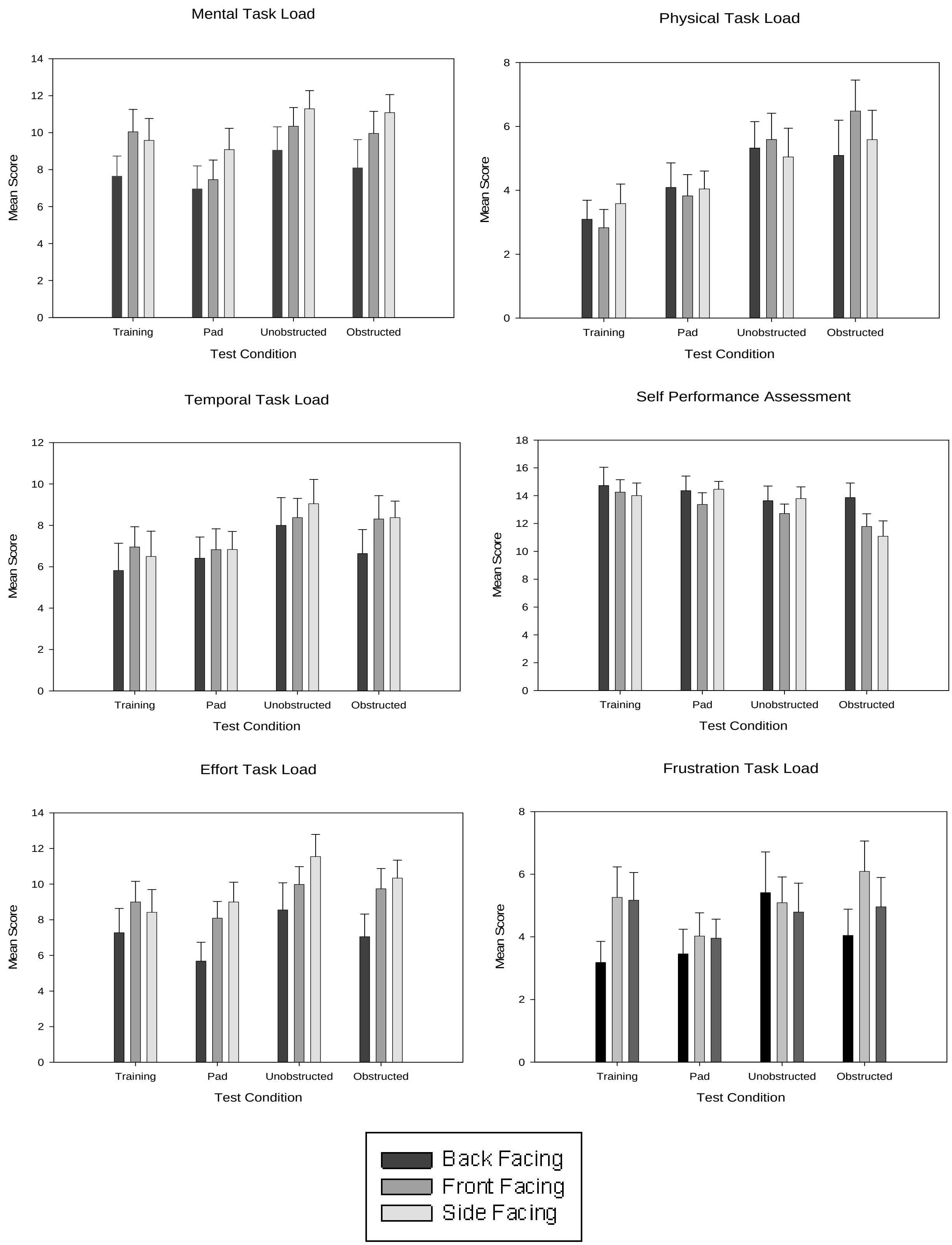

Figure 6. NASA Task Load mean scores for each measurement by test condition. The error bars represent standard errors of the means.

The second analysis was a 2 (flight condition) X 2 (flight mode) X 3 (seat position) mixed measures ANOVA, conducted on the six different NASA Task Load Index scores. The two flight conditions (within subjects) were unobstructed and obstructed flights, the two flight modes (within subjects) were smooth and vigorous flights, and the three seating positions (between subjects) were forward, side, and backward facing (figure 7). A main effect of flight mode only was found for the mental task load [$F(1, 43) = 28.546$, $p < 0.001$], physical task load [$F(1, 43) = 11.254$, $p = 0.002$], temporal task load [$F(1, 43) = 16.032$, $p < 0.001$], effort task load [$F(1, 43) = 6.451$, $p = 0.015$], and frustration task load [$F(1, 43) = 26.526$, $p < 0.001$], while all other main effects and interactions for these measurements were found to be non significant. For the self performance assessment, significant main effects were revealed for flight condition [$F(1, 43) = 6.33$, $p = 0.016$] and flight mode [$F(1, 43) = 12.801$, $p = 0.001$], while no interactions for self performance assessment were significant. For all measurements, negative significant effects were found for vigorous flight when compared to smooth flight, but only self performance demonstrated a significant difference in-flight condition, with performance ratings higher for unobstructed views than for obstructed views. See appendix H, table H-4 for all significance results.

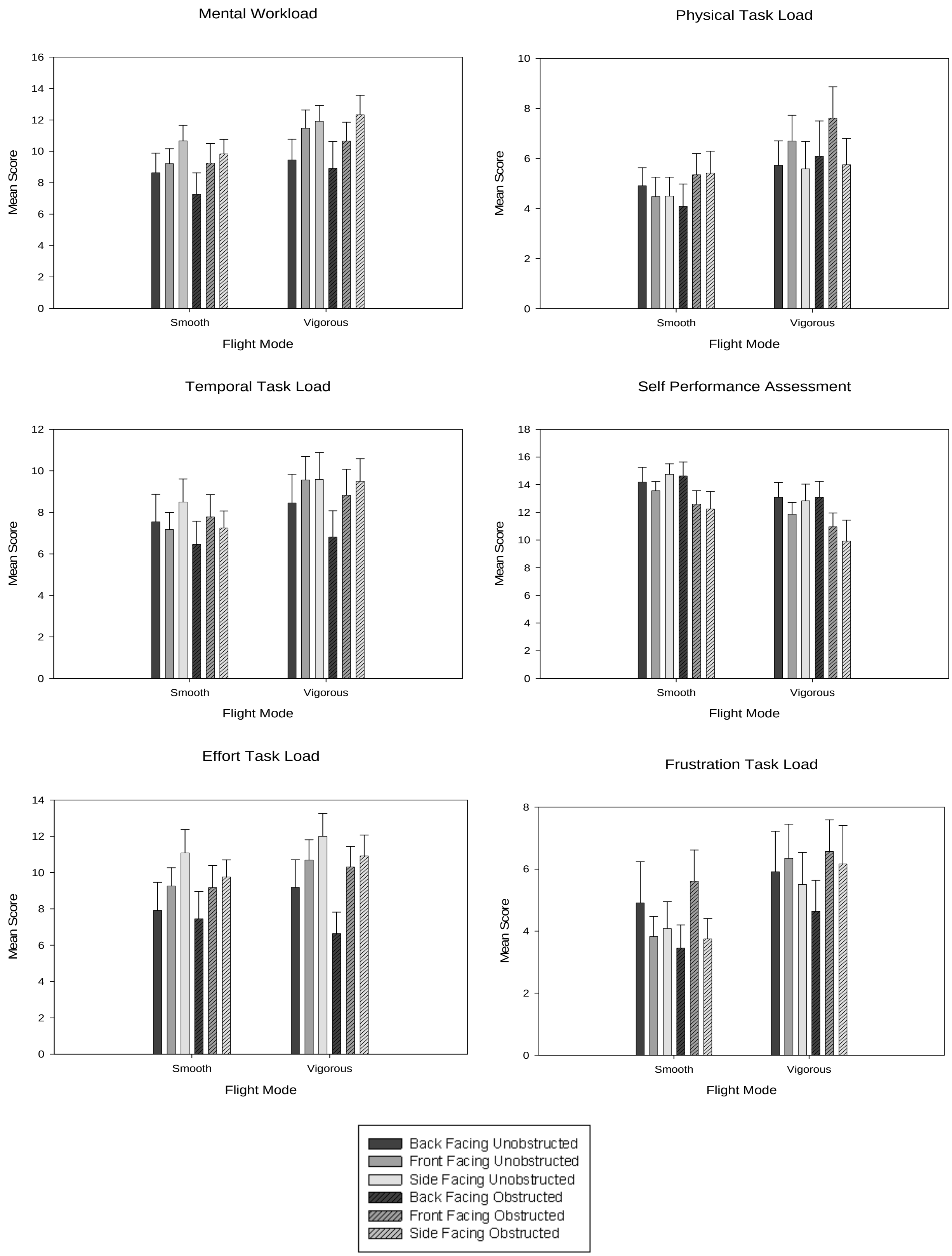

Figure 7. NASA Task Load mean scores for each measurement by flight mode. The error bars represent standard errors of the means.

The results obtained from the NASA Task Load scores suggest an overall increase in workload (and decrease in performance) for in-flight conditions over stationary ground conditions; however the pattern was not consistent. While two measures indicate deficits in performance for the pad condition only compared to in-flight conditions (Mental Task Load and Effort Task Load), both training and pad conditions were lower in Physical Demand than both in-flight conditions. Unobstructed flight required a higher Temporal Task Load than the two grounded conditions, and obstructed in-flight led to lower Self Performance Assessment in comparison to both grounded conditions. Overall though, the pattern suggests that in-flight conditions lead to overall perceived negative workloads.

When comparing flight conditions only, the vigorous flight led to decreased perceived scores for all workload measurements. Only Self Performance Assessment was influenced by the ability to view the outside world, with performance perceived as worse for conditions in which the outside world was obstructed. This negative assessment during vigorous flight suggests the limitations of operating a simulated UAS while stationed within an aerial platform exist.

Subjective Stress Rating Scale

Since this survey was given only after exiting the JUH-60, a 3 (test condition) X 3 (seat position) mixed measures ANOVA was conducted on the two different measurements of the SSRS survey. The three test conditions (within subjects) were following pad flights, following unobstructed flights, and following obstructed flights, and the three seating positions (between subjects) were forward, side, and backward facing. No significant differences were found for either the mentally or the physically perceived stresses of flying a UAS on this type of mission (figure 8). Results from the SSRS test suggests that no perceived differences existed between the two different test conditions and the seating positions. See appendix H, table H-5 for all significance results.

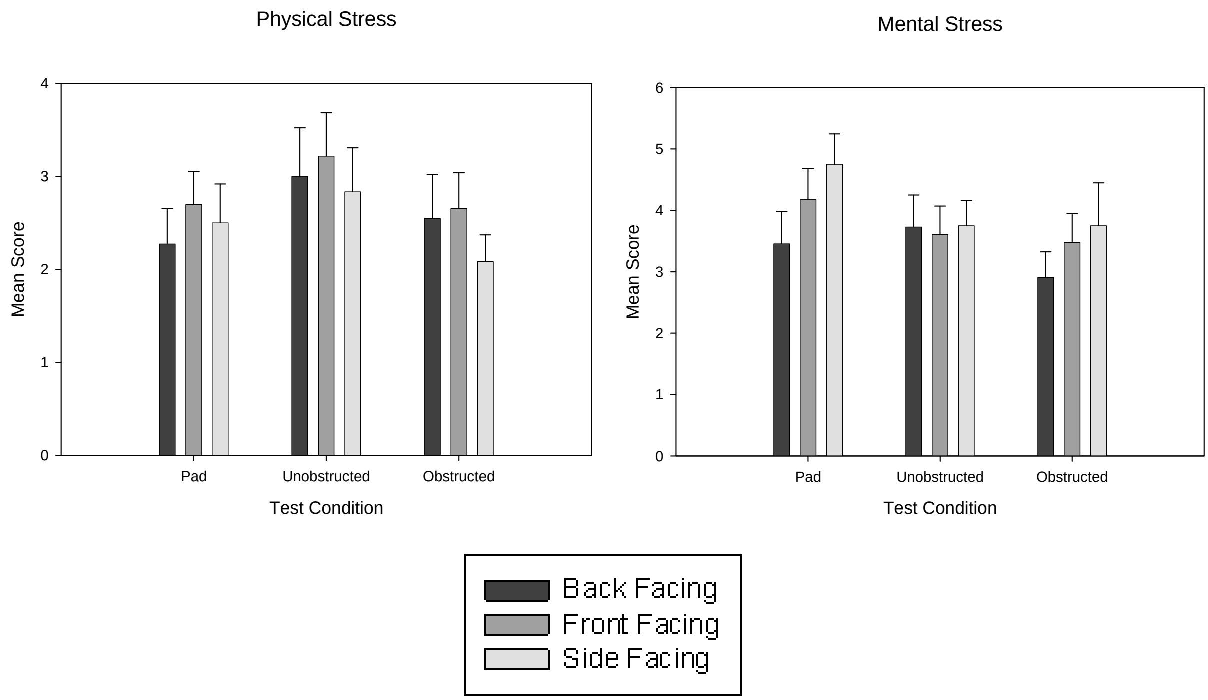

Figure 8. Subjective Stress Rating Scale mean scores for each measurement by test condition. The error bars represent standard errors of the means.

Simulated flight performance

All flight performance data reported in this study was converted to root of the mean squared errors of any deviations the pilots had from the flight profile (this treated deviations of above and below targeted measures as net errors, not errors of a positive or negative nature). Each flight profile had three distinct maneuvers, namely takeoff, level flight, and turns. During each flight, the average of all mean squared errors of flight deviations for each distinct maneuver was calculated and used for analysis (one takeoff per flight, seven turns, and eight level flights; each of these are considered individual maneuvers). Any missed individual maneuver was not used for data analysis and participants were not included if they missed more than three individual maneuvers (this excluded four participants and was most likely due to motion sickness during the task). Again, one participant missed a flight and a human error led to the loss of data for two individuals. A total of 40 participants were used for the data analysis with eight participants facing the side, 21 facing the front, and 11 facing the back. Two ANOVAs were conducted on each maneuver, 4 X 3 mixed measures ANOVA and a 2 X 2 X 3 mixed measures ANOVA with the same factors as the MSQ and NASA Task Load Index.

Takeoff performance

Data were recorded for the takeoff maneuver after passing 200 ft in altitude above the ground and until the simulated UAS flight was within 200 ft of the target altitude.[8] Each ANOVA was conducted with the three measurements (heading direction, bank angle, and climb rate) used to grade takeoff performance.

The 4 X 3 mixed measures ANOVA (figure 9) revealed a main effect of test condition for both bank angle [$F(2.556, 94.56) = 6.718$, $p = 0.001$, Greenhouse-Geisser corrected] and heading maintenance [$F(2.254, 83.381) = 3.864$, $p = 0.021$, Greenhouse-Geisser corrected] measurements, but not for climb rate ($p = 0.06$). No other significant main effects or interactions were found for any of the three measurements. Post-hoc Bonferroni corrected pairwise comparisons were conducted for the significant main effects and the results demonstrated that individuals were better at maintaining their heading and bank angle in the conference room (training) condition than in any of the helicopter conditions. See appendix H, table H-6 for all significance results.

[8] This was to reduce the amount of error that would be introduced by the low climb rate at the beginning and end of the takeoff maneuver. This maneuver covered a climb total of 1393 ft or approximately 2 minutes of flight time at the desired climb rate.

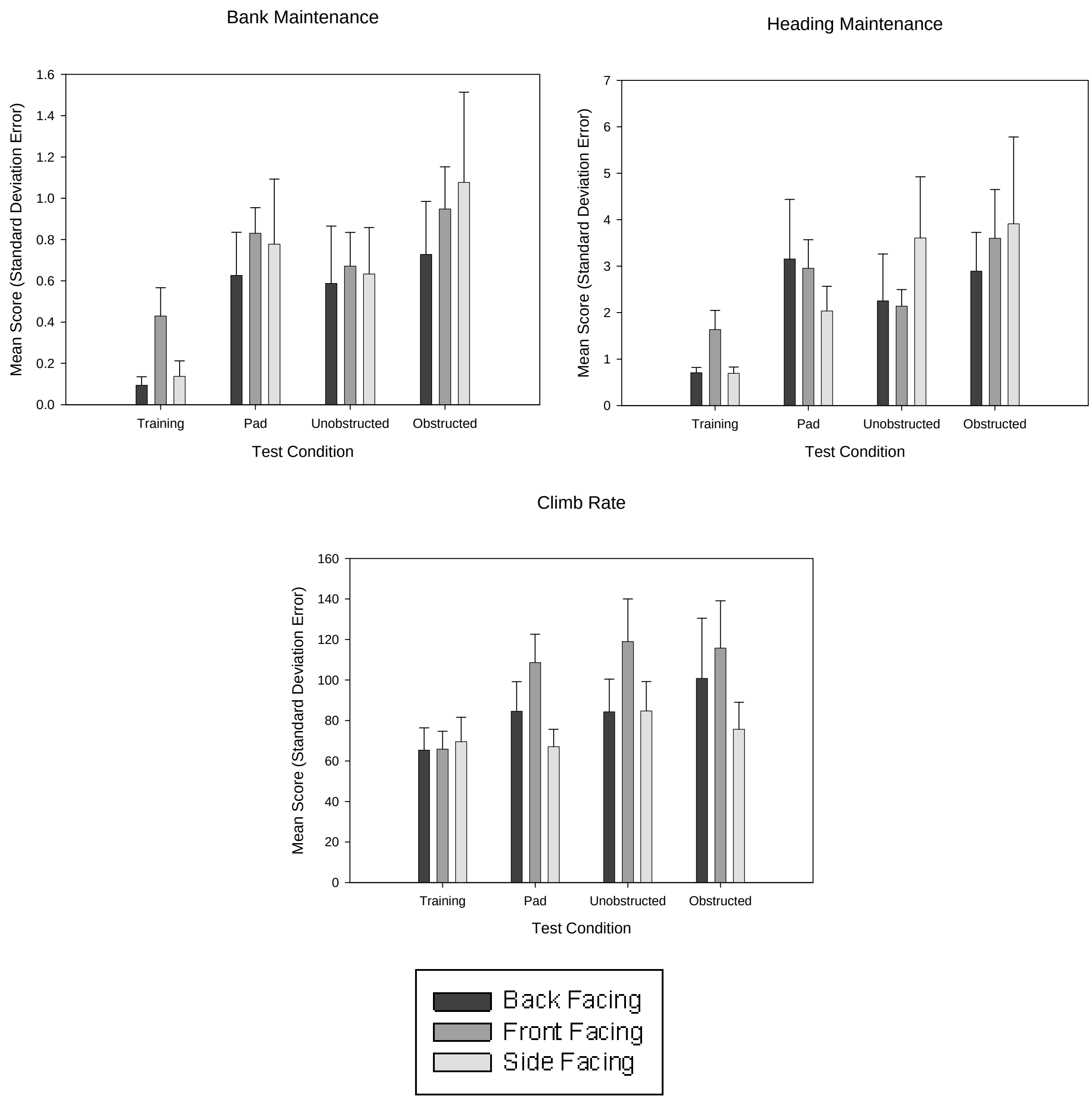

Figure 9. Takeoff flight performance mean scores for each measurement by test condition. The error bars represent standard errors of the means.

Takeoff performance was not significantly different for any of the measurements in the 2 X 2 X 3 mixed measures ANOVA. See figure 10 for means and appendix H, table H-7 for all significance results.

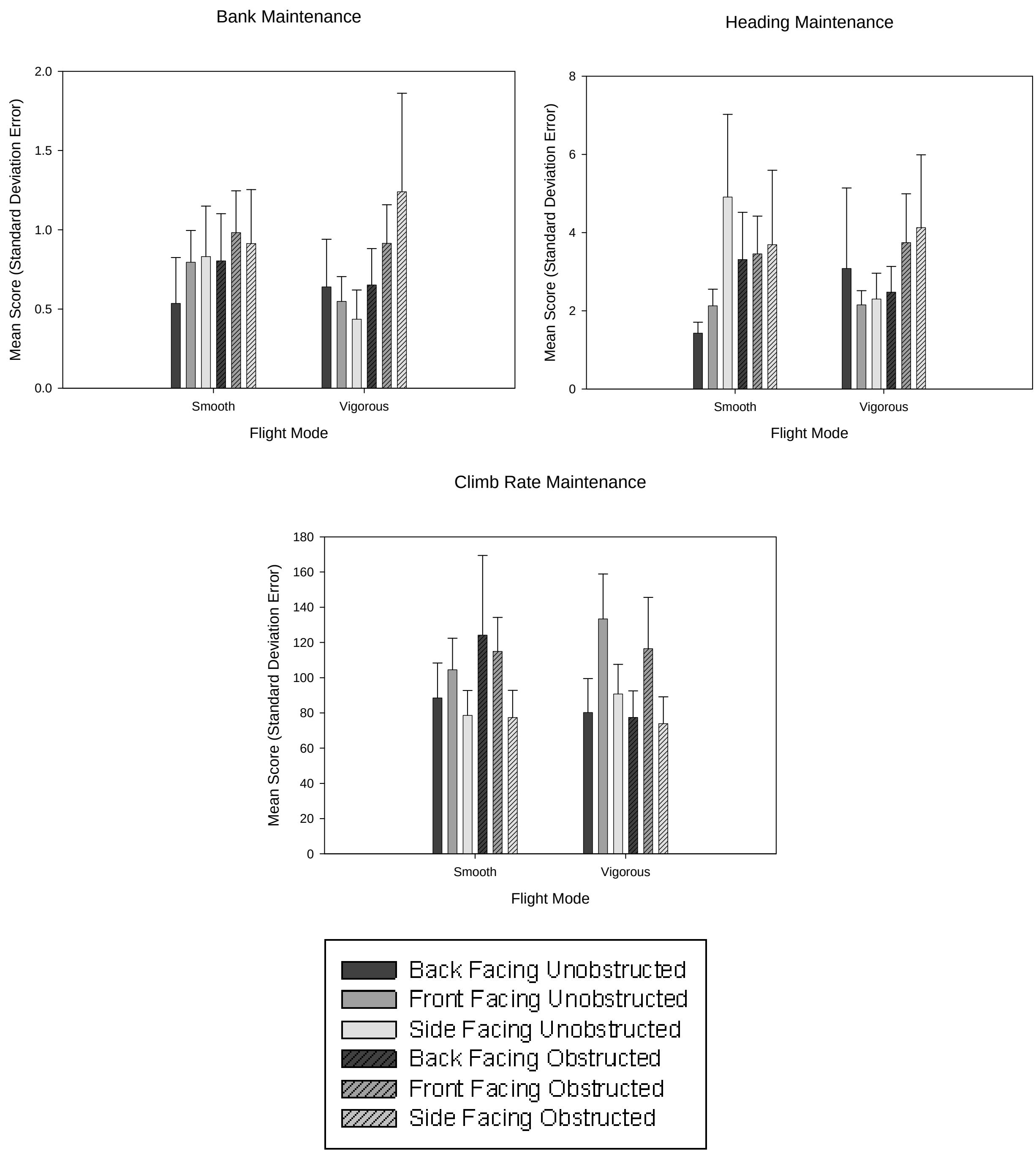

Figure 10. Takeoff performance mean scores for each measurement by flight mode. The error bars represent standard errors of the means.

<u>Turn performance</u>

Since time stamps were not consistent in the output, software was created to determine when the participant was conducting a turn and not banking the aircraft to correct their heading. The software collected samples of the flight performance at regular intervals during the flight, but the lack of consistent timestamps though prevented us from determining the sample rate of data collection. Therefore, turning parameters were set such that if the magnitude of the bank angle increased to over 18°, and was maintained for over seven samples (enough time to reach the target bank angle), then the maneuver was determined to be a turn. The turn was considered to be complete seven samples before the magnitude of the bank angle dropped below 18° thus demonstrating a level flight was beginning. Each ANOVA was conducted with the two measurements used to grade turn performance, altitude and bank maintenance.

Both the 4 X 3 and 2 X 2 X 3 mixed measures ANOVAs revealed no significant differences in any of the main effects or interactions. See figures 11 and 12 for the means and appendix H, tables H-8 and H-9 for all significance results for turn performance.

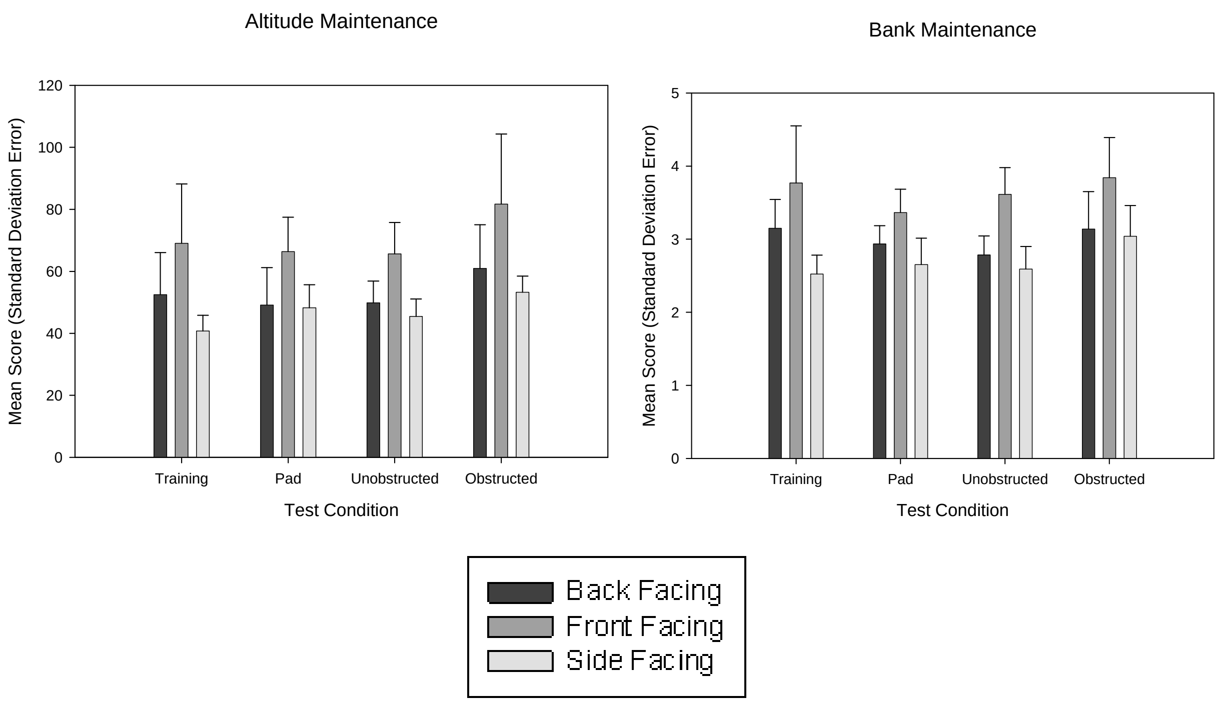

Figure 11. Turn performance mean scores for each measurement by test condition. The error bars represent standard errors of the means.

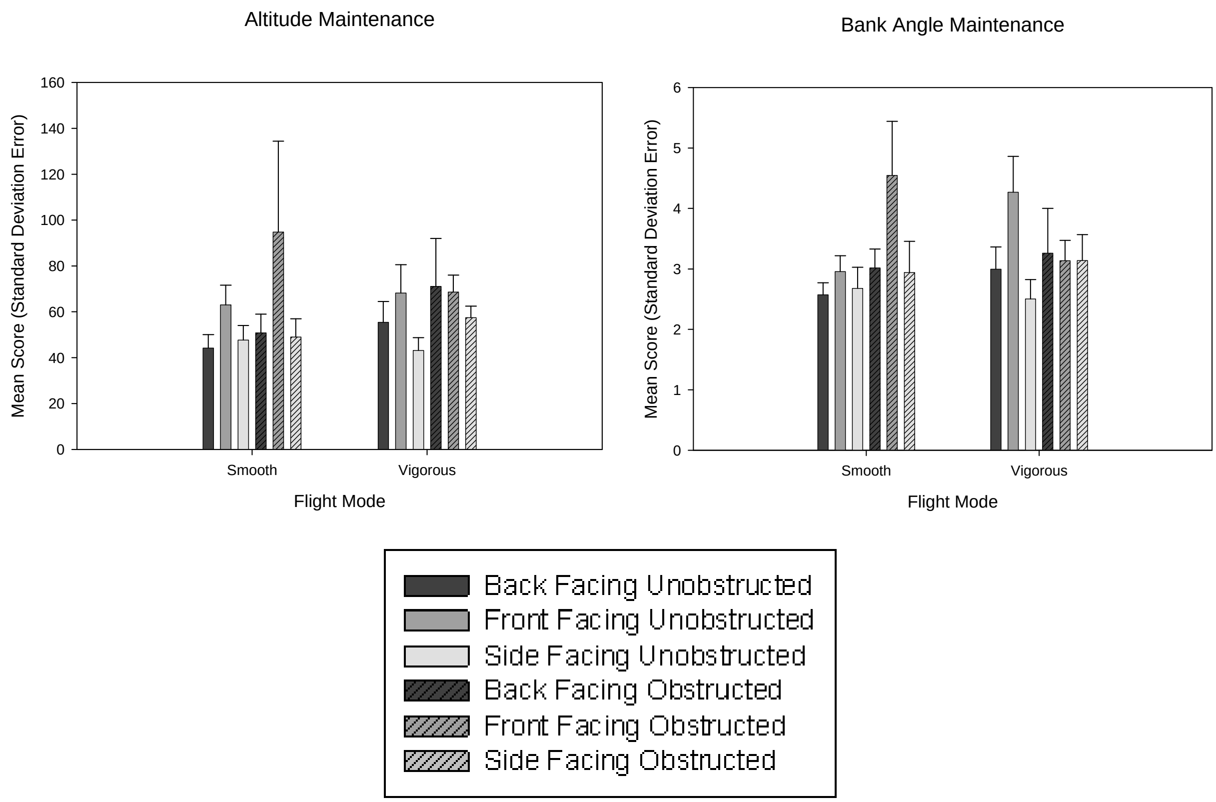

Figure 12. Turn performance mean scores for each measurement by flight mode. The error bars represent standard errors of the means.

<u>Level flight performance</u>

After takeoff, the simulated UAS was considered to be in level flight unless the data collection software determined the UAS was in a turn based on the criteria described above (see turn performance). Level flight was measured using both altitude and heading maintenance measures.

Both the 4 X 3 and 2 X 2 X 3 mixed measures ANOVAs found no significant differences in any of the main effects or interactions. See figures 13 and 14 for the means and appendix H, table H-10 and H-11 for all significance results for level flight performance.

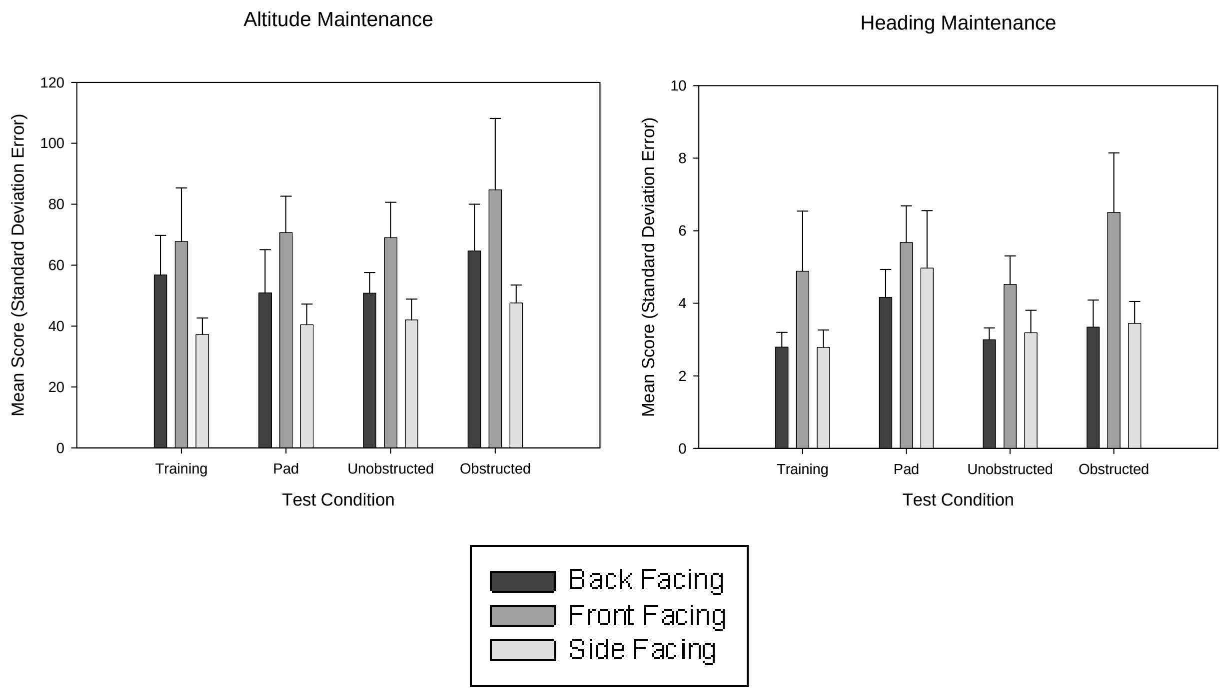

Figure 13. Level flight performance mean scores for each measurement by test condition. The error bars represent standard errors of the means.

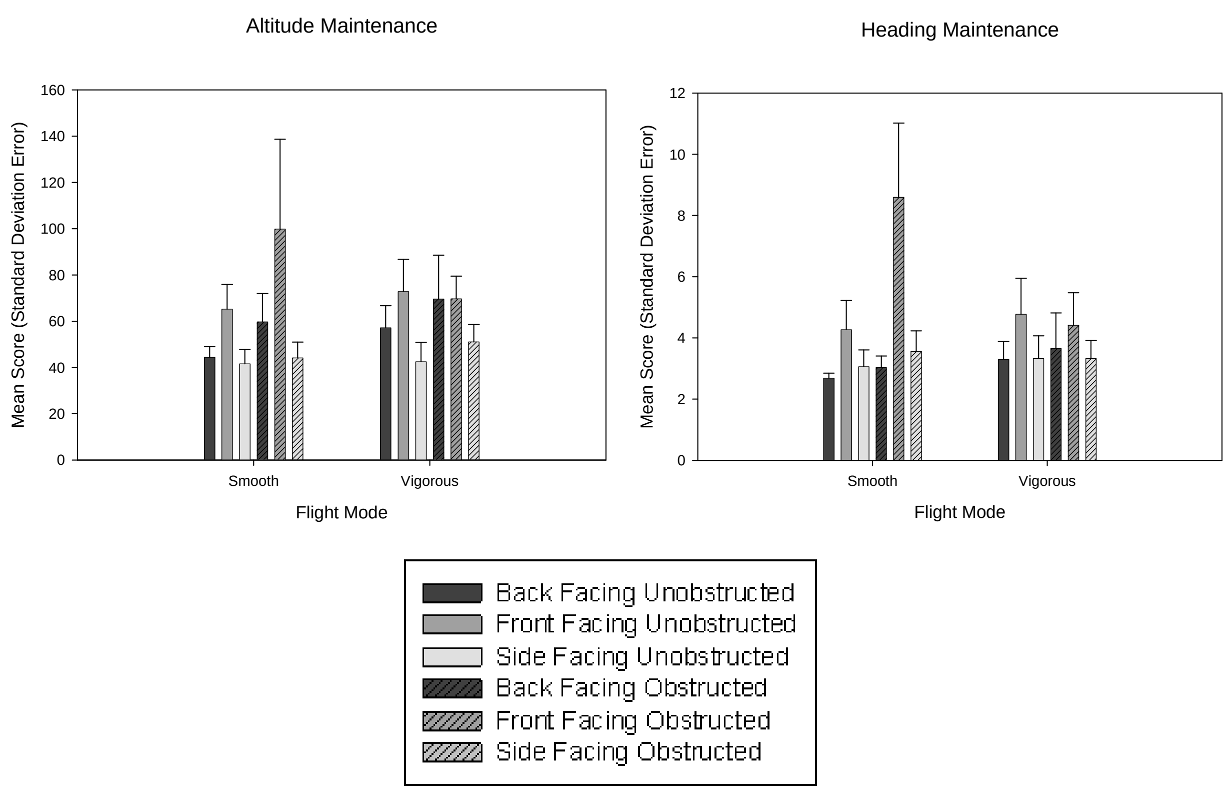

Figure 14. Level flight performance mean scores for each measurement by flight mode. The error bars represent standard errors of the means.

The training condition in this study demonstrated the participants' superior ability to maintain both initial heading and bank angle of the UAS simulated flight during the takeoff maneuver. In fact, no other maneuver led to any significant differences between the test conditions. However, the pilot of the simulated UAS flight only needed to continue flying in a constant direction and avoid any banking to obtain a good overall score at this task. Vibrations provided by the helicopter could have led to slight deviations from the desired flight path, resulting in differences between the flight conditions either by making the UAS operator's hand jitter or by causing the controller to jitter itself. One may question why this was not found in the level flight performance, but it is worth suggesting that since pilots were exiting a turn prior to starting all but one level flight, slight deviations upon exiting that turn and adjustments to correct this deviation most likely resulted in enough errors to nullify the deviations induced by the vibrations of the aircraft. This suggests that even the pad condition, with no influences of movement due to actually flying, produced deviations comparable to those of the conditions within a flying helicopter.

Task performance surveys

Post-flight questionnaire

The scores for the post-flight questionnaire were divided into groups according to the flight session and seating positions of the participants. No statistical analyses were conducted on the data, but response frequencies are included in appendix H, table H-12. Descriptive results for the post-flight questionnaire are included in appendix I. General results suggest our participants were not distracted by the outside world when it was viewable (question 6) and that participants did not have a negative experience from any of the seating positions in any of the helicopter conditions (question 1).

Post-study questionnaire

The post-study questionnaire was split into groups according to the seating positions of the individuals. Since each group consisted of a different number of individuals (11 backward facing, 23 front facing, and 12 side facing participants), frequency scores were created using the overall percentage of the groups response as opposed to using the total amount of responses for each group (figure 15). Chi Square tests were conducted on each survey question with seating position (back, front, or side facing) as the conditions. Results of the tests determined no significant differences existed ("How did you like the study," $p = 0.319$, "Did you like your seating position during the study," $p = 0.097$, "Could a UAS be piloted from the back of a helicopter," $p = 0.727$, "Which condition did you like more," $p = 0.223$, "Could you have performed better in another seat," $p = 0.082$). The results presented here further strengthen the suggestion that orientation of one's seat did not play a strong role while operating a simulated UAS from within an operational helicopter.

Overall, participants in the study felt that their seating position was not a problem and seemed to enjoy participating in the study. Participants had a strong preference for being able to view the outside world, and felt that a UAS could be piloted from the back of a helicopter, suggesting that further research in this area should be conducted.

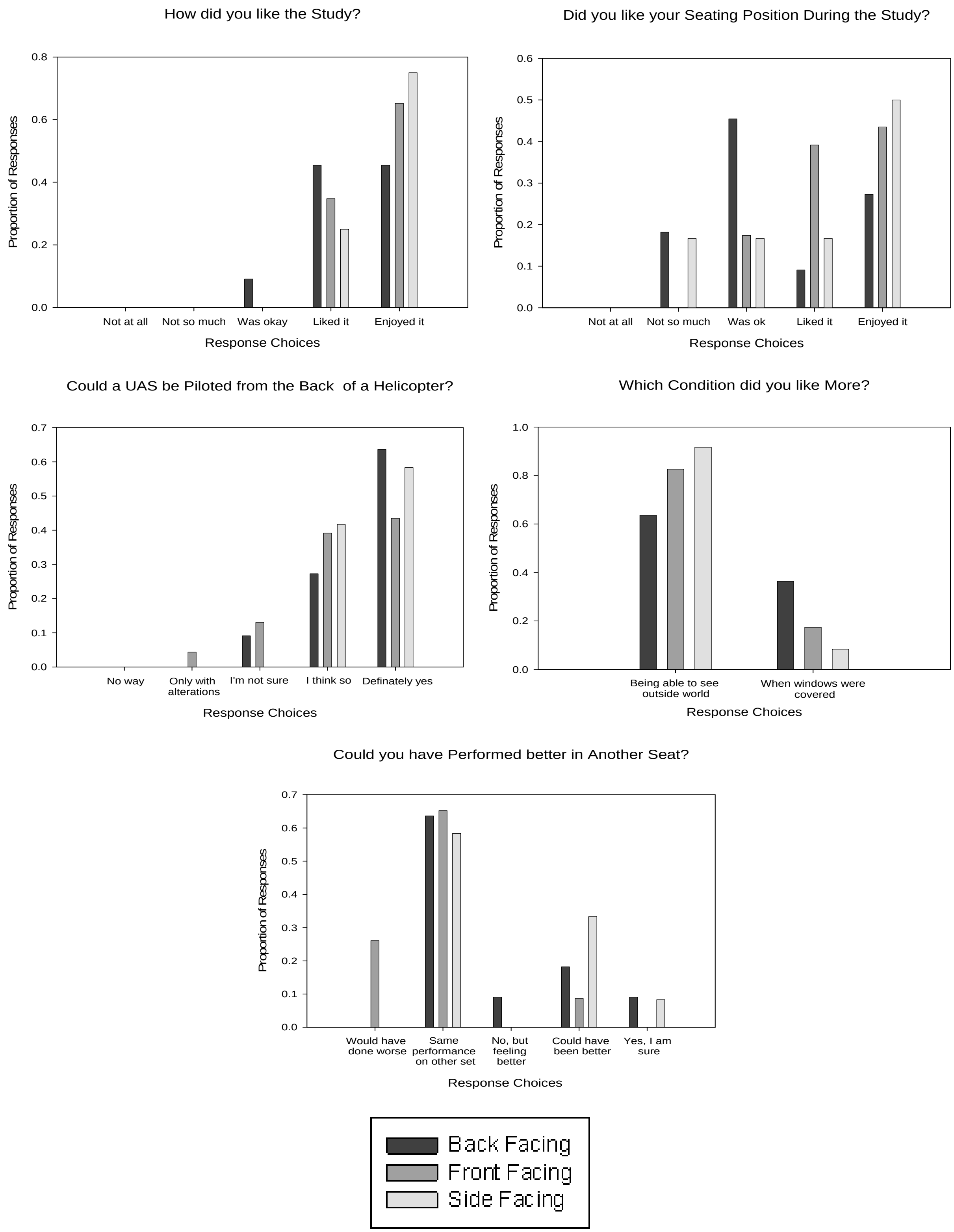

Figure 15. Post-study questionnaire proportion frequency responses for each seating position.

Overall discussion

Even though the simulated UAS flights were short (approximately 15 minutes each: 50 minutes of total daily in-flight time), participants demonstrated increased motion sickness scores when in-flight as opposed to the training and pad conditions. These increases in motion sickness scores for the MSQ surveys were highest during vigorous flights, as opposed to very small increases in motion sickness scores for grounded simulation flights. Seating position of the UAS operator did not matter, but obstructed viewing typically resulted in higher motion sickness scores, especially during vigorous flights. Overall, our results suggest that the control of a UAS within an operational UH-60 during vigorous flight leads to motion sickness symptoms and these symptoms create a situation that is non-optimal for the UAS controller. In addition, obstructing the outside world only adds to the motion sickness symptoms. This study however does not address if this non-optimal UAS controller would still result in an increase in SA for the aircrew over normal circumstances, and future research is necessary to determine the overall change in SA in this scenario.

The NASA Task Load Index results agree with the findings of the MSQ scores. NASA Task Load Index responses indicated that vigorous flights were perceived to result in an increase of workload for the UAS operator for all measurements. This again suggests that UAS operators have added difficulty in their task while stationed within an in-flight vehicle. Whether this perceived difficulty is directly due to a feeling of motion sickness cannot be determined by this study, but it would seem probable that feeling ill would lead to a negative perception of task performance.

The flight performance of the simulated UAS operators indicated no significant differences for any maneuver except for the takeoff maneuver. During takeoff, simulated UAS operators were able to maintain their heading and a lack of banking better in the training condition over any conditions held inside of the helicopter. This superior performance during the training session only leads the researchers to speculate that the benefit may be due to the vibrations of the helicopter itself and not from simply being in-flight, but further research would be needed to determine this. If takeoff performance of the UAS is negatively influenced by having the operator stationed within a flying aircraft, then the UAS should not be under the control of the in-flight operator until after UAS takeoff. This transfer of operators is possible and should not lead to decrements in MUM teaming.

Study limitations

Two shortcomings concerning motion sickness exist in this study. First, no baseline was established for motion sickness scores while riding in an operating UH-60 during flight while not operating a simulated UAS. It is unknown at this time whether or not just riding in the rear of the helicopter during flight would lead to the motion sickness symptoms found in our participants. However, the only comparison that can be made from this study is that all vomiting was done by participants who were operating the simulated UAS, while no vomiting was done by research staff within the helicopter. Our participants did not indicate a of history of suffering from motion sickness, which may suggest the task of controlling the simulated UAS while in an in-flight helicopter resulted in their increased motion sickness scores and symptoms. The second limitation is that vigorous flights always followed smooth flights, and vigorous flights resulted in increased motion sickness scores, which could result in an increase of motion sickness symptoms due to the amount of time in the helicopter. However, it would not have been practical to counterbalance vigorous and smooth flights due to the increased risk of motion sickness following vigorous flights.

Conclusion

Overall, the results of this study suggest that MUM teaming can be accomplished without significant degradation of UAS control, but the issue of motion sickness exists for the UAS operator. Since our simulated UAS flights were relatively short (approximately 50 minutes of total flight time), it is unknown how prolonged exposure of operating a UAS during MUM teaming would impact motion sickness, and how this would influence flight performance of the UAS, or if over time MUM UAS operators would adjust and no longer experience motion sickness. Future studies are needed to address these issues and to further determine the costs and benefits of MUM teaming.

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Appendix A.

Pre-study questionnaire.

Dear Participant,

This questionnaire will help identify eligible participants. Be assured that none of your personal data (such as name, date of birth) will be given away to a third party or will be used for anything other than study purposes. After completing the first page of the pre-study questionnaire (questions A to D) a unique code will be assigned to your data and your identifying info (page one) will be kept at a separate and secure place. If any data (such as age) needs be used in the analysis of data from our main task we will identify the information with the unique code.

A) Name: ____

B) Date of Birth: ____

C) Rank: ____

D) Contact phone number (day): ____

E) Assigned subject number: ____

Subject Number: ____

Answering each question is important to this study; however,
you have the right to refuse answering specific questions without repercussion.

1. Are you active duty military?

2. How many flights as a helicopter passenger did you experience during the last 10 years (approximately)?

3. Do you have experience in piloting a full-scale aircraft?
   If yes, how many hours of experience do you have?

4. Do you have experience in a training flight simulator (not PC-based software)?
   If yes, how many hours of experience do you have?

5. Do you have experience in using a PC based flight simulator?
   If yes, how many hours of experience do you have?

6. Do you have experience in piloting a RC model aircraft?
   If yes, how many hours of experience do you have?

7. Do you have experience in controlling unmanned aircraft systems (UAS)?
   If yes, how many hours of experience do you have?

8. Are you right- or left-handed (or ambidextrous)?

9. Are you taking any type of medication at the moment or on a regular basis?
   If yes, state reason, medication and frequency.

Appendix B.

Motion History Questionnaire.

Answering each question is important to this study; however,
you have the right to refuse answering specific questions without repercussion.

Subject Code: _______________ Date: ________________

1. Approximately how many total flight hours do you have? _____hours
2. How often would you say you get airsick?
   Always____ Frequently ____ Sometimes ____ Rarely ____ Never _____
3. a) How many total flight simulator hours? _____hours
   b) How often have you been in a virtual reality device? _____times _____hours
4. How much experience have you had at sea aboard ships or boats?
   Much ____ Some ____ Very Little ____ None ____
5. From your experience at sea, how often would you say you get seasick?
   Always ____ Frequently ____ Sometimes ____ Rarely ____ Never ____
6. Have you ever been motion sick under any conditions other than the ones listed so far?
   No ____ Yes ____ If so, under what conditions? _____________________________
7. In general, how susceptible to motion sickness are you?
   Extremely ____ Very ____ Moderately ____ Minimally ____ Not at all ____
8. Have you been nauseated FOR ANY REASON during the past eight weeks?
   No ____ Yes ____ If yes, explain ____
9. When you were nauseated for any reason (including flu, alcohol, etc.), did you vomit?
   Easily ____ Only with difficulty ____ Retch and finally vomit with great difficulty ____
10. If you vomited while experiencing motion sickness, did you?
    a) Feel better and remain so? ____
    b) Feel better temporarily, then vomit again? ____
    c) Feel no better, but not vomit again? ____
    d) Other – specify ____

11. If you were in an experiment where 50% of the subjects get sick, what do you think your chances of getting sick would be? Almost certainly would ____ Probably would ____ Almost probably would not ____ Certainly would not ____

12. Would you volunteer for an experiment where you knew that: (Please answer all three)
    a) 50% of the subjects did get motion sick? Yes ____ No ____
    b) 75% of the subjects did get motion sick? Yes ____ No ____
    c) 85% of the subjects did get motion sick? Yes ____ No ____

13. Most people experience slight dizziness (not a result of motion) three to five times a year. The past year have you been dizzy:
    More than this ____ The same as ____ Less than ____ Never dizzy ____
14. Have you ever had an ear illness or injury which was accompanied by dizziness and/or nausea?

Yes ____ No ____

15. Listed below are a number of situations in which some people have reported motion sickness. In the space provided, check (a) your PREFERANCE for each activity (that is how much you like the activity), and (b) any SYMPTOM(s) you may have experienced any time, past or present.

SITUATIONS **PREFERENCE** **SYMPTOMS**

	LIKE	NEUTRAL	DISLIKE	VOMITED	NAUSEA	STOMACH AWARENESS*	INCREASED SALIVATION	DIZZINESS	DROWSINESS	SWEATING	PALLOR	VERTIGO**	AWARENESS OF BREATHING	HEADACHE	OTHER SYMPTOMS	NONE
Aircraft																
Flight Simulator																
Roller Coaster																
Merry-go-round																
Other carnival ride																
Automobiles																
Long train or Bus ride																
Swings																
Hammocks																
Gymnastic Apparatus																
Roller/Ice skating																
Elevators																
Cinerama or Wide screen movies																
Motorcycles																

* Stomach awareness refers to a feeling of discomfort that is preliminary to nausea.

* * Vertigo is experienced as loss of orientation with respect to vertical upright.

Appendix C.

Motion Sickness Questionnaire.

Subject Code: _______________ Administered: ________________

Answering each question is important to this study; however,
you have the right to refuse answering specific questions without repercussion.

For each symptom, please circle the rating that applies to you **RIGHT NOW**.

	1	2	3	4
General discomfort	None	Slight	Moderate	Severe
Fatigue	None	Slight	Moderate	Severe
Boredom	None	Slight	Moderate	Severe
Drowsiness	None	Slight	Moderate	Severe
Headache	None	Slight	Moderate	Severe
Eye Strain	None	Slight	Moderate	Severe
Difficulty focusing	None	Slight	Moderate	Severe
Increased salivation	None	Slight	Moderate	Severe
Decreased salivation	None	Slight	Moderate	Severe
* Sweating	None	Slight	Moderate	Severe
Nausea	None	Slight	Moderate	Severe
Difficulty concentrating	None	Slight	Moderate	Severe
Mental depression	No	Yes		
“Fullness of the head”	No	Yes		
Blurred vision	No	Yes		
Dizziness with eyes open	No	Yes		
Dizziness with eyes closed	No	Yes		
Vertigo	No	Yes		
** Visual flashbacks	No	Yes		
Faintness	No	Yes		
Aware of breathing	No	Yes		
*** Stomach awareness	No	Yes		
Loss of appetite	No	Yes		
Increased appetite	No	Yes		
Desire to move bowels	No	Yes		
Confusion	No	Yes		
Burping	No	Yes		
Vomiting	No	Yes		

Other: please specify:

____

____

____

____

____

*   Sweating “Cold sweats” due to discomfort not due to physical exertion.

** Visual flashback – Illusion of movement or false sensation similar to aircraft dynamics when not in the simulator or aircraft.

*** Stomach Awareness – used to indicate a feeling of discomfort just short of nausea.

Appendix D.

Task Load Index (TLX).

Answering each question is important to this study; however,
you have the right to refuse answering specific questions without repercussion.

NASA TLX Workload Assessment Instructions

We are interested in the "workload" you experienced during this flight. Workload is something experienced individually by each person. One way to find out about workload is to ask people to describe what they experienced. Workload may be caused by many different factors and we would like you to evaluate them individually. The set of six workload rating factors was developed for you to use in evaluating your experiences during different tasks. Please read them. If you have a question about any of the scales in the table, please ask about it. It is extremely important that they be clear to you.

Definitions

Title	End Points	Descriptions
MENTAL DEMAND	Low / High	How much mental and perceptual activity was required (that is, thinking, deciding, calculating, remembering, looking, searching, etc.)? Was the task easy or demanding, simple or complex, exacting or forgiving?
PHYSICAL DEMAND	Low / High	How much physical activity was required (that is, pushing, pulling, turning, controlling, activating, etc.)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?
TEMPORAL DEMAND	Low / High	How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?
PERFORMANCE	Poor / Good	How successful do you think you were in accomplishing the goals of the task? How satisfied were you with your performance in accomplishing these goals?
EFFORT	Low / High	How hard did you have to work (mentally and physically) to accomplish your level of performance?
FRUSTRATION LEVEL	Low / High	How insecure, discouraged, irritated, stressed, and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?

We want you to evaluate workload for the flight that you participated in today. Rate the workload on each factor on a scale. Each scale has two end descriptions, and 20 slots (hash marks) between the end descriptions. Place an "x" in the slot (between the hash marks) that you feel most accurately reflects your workload. This includes all the duties involved in your job (e.g., preparing your workstation, using displays and controls at your workstation).

TLX – Workload Scale

Subject Code: _______________ Administered: ________________

Please rate your workload by putting a mark on each of the six scales at the point which matches your experience.

Mental Demand

Very Low Very High

Physical Demand

Very Low Very High

Temporal Demand

Very Low Very High

Performance

Very Poor Very Good

Effort

Very Low Very High

Frustration

Very Low Very High

Appendix E.

Subjective Stress Rating Scale.

Subject Code: _______________ Administered: ________________

Answering each question is important to this study; however,
you have the right to refuse answering specific questions without repercussion.

1. The scale below represents a range of how PHYSICALLY stressful the mission might be. Check the block indicating how PHYSICALLY stressful the mission you just participated in was.

Task	Not at All Stressful 1	2	3	4	5	6	7	8	9	Most Possible Stress 10
a. Overall stress										

2. The scale below represents a range of how MENTALLY stressful the mission might be. Check the block indicating how MENTALLY stressful the mission that you just participated in was.

Task	Not at All Stressful 1	2	3	4	5	6	7	8	9	Most Possible Stress 10
a. Overall stress										

Appendix F.

Post-flight questionnaire.

Subject Code: _______________ Administered: ________________

Answering each question is important to this study; however,
you have the right to refuse answering specific questions without repercussion.

1. How much did you enjoy your helicopter ride today?

☐	☐	☐	☐	☐
not at all	not so much	was okay	liked it	enjoyed it

2. How much did you eat at your last meal before takeoff?

☐	☐	☐	☐	☐
nothing	few	medium	regular	much

3. How long ago was your last meal before takeoff?

☐	☐	☐	☐	☐
> 6 hours	4 – 6 hours	2 – 4 hours	1 – 2 hours	< 1 hour

4. How much did you drink during the last 3 hours prior to takeoff?

☐	☐	☐	☐	☐
nothing	few	medium	regular	much

5. When did you drink your last alcoholic beverage before takeoff?

☐	☐	☐	☐	☐
> 24 hours	18 - 24 hours	12 - 18 hours	6 - 12 hours	< 6 hour

6. Have you been distracted by anything during the flight? If yes, please specify:

____

____

7. Have you been distracted by the outside world view (through the helicopters' windows)?

☐	☐	☐	☐	☐
not at all	not so much	quite a bit	was distracted	very much

8. Compared to taking the given task in a calm, non-moving office environment, how much do you think that performing the task in the helicopter impaired your performance today?

☐	☐	☐	☐	☐
not at all	not so much	quite a bit	definitely	very much

9. Did you take any type of medication during the last 24 hours? If yes, please specify:

____

Appendix G.

Post-study questionnaire.

Subject Code: _______________ Administered: ________________

Dear Participant,

This post-study questionnaire is concluding your part in the study. We would like to thank you very much for volunteering!!!

Answering each question is important to this study; however,
you have the right to refuse answering specific questions without repercussion.

1. How did you like the study? Did you enjoy participating?

☐ not at all ☐ not so much ☐ was okay ☐ liked it ☐ enjoyed it

2. Do you think that in a future scenario the controller of a UAS could "pilot" a remote controlled vehicle from the back of a helicopter?

☐ no way ☐ only with alterations ☐ I'm not sure ☐ I think so ☐ definitely yes

3. Which was your seating position in the helicopter?

☐ forward facing ☐ aft facing ☐ facing to the side

4. Did you like your seating position during the study?

☐	☐	☐	☐	☐
not at all	not so much	was okay	liked it	enjoyed it

5. Do you think you could have performed better when seated in another place in the helicopter?

☐	☐	☐	☐	☐
would have done worse	Same performance on other seat	no, but feeling better	could have been better	yes, I am sure

6. Which condition did you like more, during your flight conditions?

☐	☐
being able to see the outside world	when windows were covered

7. Is there anything else that would have helped you to perform better in our study?

____

8. Is there anything else that you would like to tell us concerning the theme of our study?

____

Thank you, we really appreciate your participation and your efforts!

Appendix H.

Results from statistical analyses.

Table H-1.
MSQ Task: 4 X 3 ANOVA.

Measurement	Effect		*p*-value
Nausea	Main‡	Test Condition	< 0.001*
	Pairwise Comparison†	Training – Pad	0.188
	Pairwise Comparison†	Training – Unobstructed	0.010*
	Pairwise Comparison†	Training – Obstructed	< 0.001*
	Pairwise Comparison†	Pad – Unobstructed	0.028*
	Pairwise Comparison†	Pad – Obstructed	<0.001*
	Pairwise Comparison†	Obstructed – Unobstructed	0.282
	Main	Seat Position	0.687
	Interaction‡	Test Condition X Seat Position	0.699
Oculomotor	Main‡	Test Condition	<0.001*
	Pairwise Comparison†	Training – Pad	1.000
	Pairwise Comparison†	Training – Unobstructed	0.043*
	Pairwise Comparison†	Training – Obstructed	0.004*
	Pairwise Comparison†	Pad – Unobstructed	0.042*
	Pairwise Comparison†	Pad – Obstructed	0.002*
	Pairwise Comparison†	Obstructed – Unobstructed	1.000
	Main	Seat Position	0.559
	Interaction‡	Test Condition X Seat Position	0.637

Disorientation	Main‡	Test Condition	<0.001*
	Pairwise Comparison†	Training – Pad	1.000
	Pairwise Comparison†	Training – Unobstructed	0.015*
	Pairwise Comparison†	Training – Obstructed	0.002*
	Pairwise Comparison†	Pad – Unobstructed	0.016*
	Pairwise Comparison†	Pad – Obstructed	0.001*
	Pairwise Comparison†	Obstructed – Unobstructed	0.781
	Main	Seat Position	0.319
	Interaction‡	Test Condition X Seat Position	0.257
Total	Main‡	Test Condition	<0.001*
	Pairwise Comparison†	Training – Pad	0.430
	Pairwise Comparison†	Training – Unobstructed	0.009*
	Pairwise Comparison†	Training – Obstructed	<0.001*
	Pairwise Comparison†	Pad – Unobstructed	0.014*
	Pairwise Comparison†	Pad – Obstructed	<0.001*
	Pairwise Comparison†	Obstructed – Unobstructed	0.345
	Main	Seat Position	0.562
	Interaction‡	Flight X Seat Position	0.577

* Indicates result is significant, †Indicates test was Bonferroni corrected, ‡Indicates test was Greenhouse-Geisser corrected

Table H-2.

MSQ Task: 2 X 2 X 3 ANOVA.

Measurement	Effect		*p*-value
Nausea	Main	Flight Condition	0.047*
	Main	Flight Mode	<0.001*
	Main	Seat Position	0.709
	Interaction	Flight Condition X Flight Mode	0.054
	Interaction	Flight Condition X Seat Position	0.396
	Interaction	Flight Mode X Seat Position	0.399
	Interaction	Flight Condition X Flight Mode X Seat Position	0.438
Oculomotor	Main	Flight Condition	0.170
	Main	Flight Mode	<0.001*
	Main	Seat Position	0.724
	Interaction	Flight Condition X Flight Mode	0.011*
	Pairwise Comparison†	Unobstructed Smooth Flight X Unobstructed Vigorous Flight	0.006
	Pairwise Comparison†	Unobstructed Smooth Flight X Obstructed Smooth Flight	1.000
	Pairwise Comparison†	Unobstructed Smooth Flight X Obstructed Vigorous Flight	<0.005
	Pairwise Comparison†	Unobstructed Vigorous Flight X Obstructed Smooth Flight	0.054
	Pairwise Comparison†	Unobstructed Vigorous Flight X Obstructed Vigorous Flight	0.066
	Pairwise Comparison†	Obstructed Smooth Flight X Obstructed Vigorous Flight	<0.005
	Interaction	Flight Condition X Seat Position	0.124
	Interaction	Flight Mode X Seat Position	0.706

Oculomotor	Interaction	Flight Condition X Flight Mode X Seat Position	0.915
Disorientation	Main	Flight Condition	0.130
	Main	Flight Mode	<0.001*
	Main	Seat Position	0.276
	Interaction	Flight Condition X Flight Mode	0.055
	Interaction	Flight Condition X Seat Position	0.174
	Interaction	Flight Mode X Seat Position	0.299
	Interaction	Flight Condition X Flight Mode X Seat Position	0.946
Total	Main	Flight Condition	0.057
	Main	Flight Mode	<0.001*
	Main	Seat Position	0.632
	Interaction	Flight Condition X Flight Mode	0.016*
	Interaction	Flight Condition X Seat Position	0.195
	Interaction	Flight Mode X Seat Position	0.440
	Interaction	Flight Condition X Flight Mode X Seat Position	0.676

* Indicates result is significant, †Indicates test was Bonferroni corrected, ‡Indicates test was Greenhouse-Geisser corrected

<u>Table H-3.</u>

NASA Task Load Index: 4 X 3 ANOVA.

Measurement	Effect		*p*-value
Mental Task Load	Main‡	Test Condition	0.003*
	Pairwise Comparison†	Training – Pad	0.453
	Pairwise Comparison†	Training – Unobstructed	0.472
	Pairwise Comparison†	Training – Obstructed	1.000
	Pairwise Comparison†	Pad – Unobstructed	<0.001*
	Pairwise Comparison†	Pad – Obstructed	<0.001*
	Pairwise Comparison†	Obstructed – Unobstructed	1.000
	Main	Seat Position	0.399
	Interaction‡	Test Condition X Seat Position	0.656
Physical Task Load	Main‡	Test Condition	<0.001*
	Pairwise Comparison†	Training – Pad	0.410
	Pairwise Comparison†	Training – Unobstructed	<0.001*
	Pairwise Comparison†	Training – Obstructed	0.001*
	Pairwise Comparison†	Pad – Unobstructed	0.001*
	Pairwise Comparison†	Pad – Obstructed	<0.001*
	Pairwise Comparison†	Obstructed – Unobstructed	1.000
	Main	Seat Position	0.962
	Interaction‡	Test Condition X Seat Position	0.307
Temporal Task Load	Main‡	Test Condition	0.004*
	Pairwise Comparison†	Training – Pad	1.000
	Pairwise Comparison†	Training – Unobstructed	0.006*
	Pairwise Comparison†	Training – Obstructed	0.395
	Pairwise Comparison†	Pad – Unobstructed	0.013*
	Pairwise Comparison†	Pad – Obstructed	0.069

Temporal Task Load	Pairwise Comparison†	Obstructed – Unobstructed	1.000
	Main	Seat Position	0.773
	Interaction‡	Test Condition X Seat Position	0.902
Self Performance Assessment	Main‡	Test Condition	0.002*
	Pairwise Comparison†	Training – Pad	1.000
	Pairwise Comparison†	Training – Unobstructed	0.612
	Pairwise Comparison†	Training – Obstructed	0.011*
	Pairwise Comparison†	Pad – Unobstructed	0.995
	Pairwise Comparison†	Pad – Obstructed	0.013*
	Pairwise Comparison†	Obstructed – Unobstructed	0.094
	Main	Seat Position	0.603
	Interaction‡	Test Condition X Seat Position	0.405
Effort Task Load	Main‡	Test Condition	0.001*
	Pairwise Comparison†	Training – Pad	1.000
	Pairwise Comparison†	Training – Unobstructed	0.005*
	Pairwise Comparison†	Training – Obstructed	1.000
	Pairwise Comparison†	Pad – Unobstructed	0.001*
	Pairwise Comparison†	Pad – Obstructed	0.014*
	Pairwise Comparison†	Obstructed – Unobstructed	0.637
	Main	Seat Position	0.259
	Interaction‡	Test Condition X Seat Position	0.610
Frustration Task Load	Main‡	Test Condition	0.077
	Main	Seat Position	0.618
	Interaction‡	Test Condition X Seat Position	0.401

* Indicates result is significant, †Indicates test was Bonferroni corrected, ‡Indicates test was Greenhouse-Geisser corrected

Table H-4.

NASA Task Load Index: 2 X 2 X 3 ANOVA.

Measurement	Effect		*p*-value
Mental Task Load	Main	Flight Condition	0.321
	Main	Flight Mode	<0.001*
	Main	Seat Position	0.370
	Interaction	Flight Condition X Flight Mode	0.381
	Interaction	Flight Condition X Seat Position	0.852
	Interaction	Flight Mode X Seat Position	0.667
	Interaction	Flight Condition X Flight Mode X Seat Position	0.089
Physical Task Load	Main	Flight Condition	0.294
	Main	Flight Mode	0.002
	Main	Seat Position	0.768
	Interaction	Flight Condition X Flight Mode	0.764
	Interaction	Flight Condition X Seat Position	0.461
	Interaction	Flight Mode X Seat Position	0.299
	Interaction	Flight Condition X Flight Mode X Seat Position	0.393
Temporal Task Load	Main	Flight Condition	0.246
	Main	Flight Mode	<0.001*
	Main	Seat Position	0.690
	Interaction	Flight Condition X Flight Mode	0.615
	Interaction	Flight Condition X Seat Position	0.646
	Interaction	Flight Mode X Seat Position	0.368
	Interaction	Flight Condition X Flight Mode X Seat Position	0.083

Self Performance Assessment	Main	Flight Condition	0.016*
	Main	Flight Mode	0.001*
	Main	Seat Position	0.467
	Interaction	Flight Condition X Flight Mode	0.593
	Interaction	Flight Condition X Seat Position	0.060
	Interaction	Flight Mode X Seat Position	0.818
	Interaction	Flight Condition X Flight Mode X Seat Position	0.886
Effort Task Load	Main	Flight Condition	0.106
	Main	Flight Mode	0.015*
	Main	Seat Position	0.222
	Interaction	Flight Condition X Flight Mode	0.162
	Interaction	Flight Condition X Seat Position	0.611
	Interaction	Flight Mode X Seat Position	0.413
	Interaction	Flight Condition X Flight Mode X Seat Position	0.197
Frustration Task Load	Main	Flight Condition	0.869
	Main	Flight Mode	<0.001*
	Main	Seat Position	0.770
	Interaction	Flight Condition X Flight Mode	0.813
	Interaction	Flight Condition X Seat Position	0.051
	Interaction	Flight Mode X Seat Position	0.569
	Interaction	Flight Condition X Flight Mode X Seat Position	0.099

* Indicates result is significant, †Indicates test was Bonferroni corrected, ‡Indicates test was Greenhouse-Geisser corrected

Table H-5.

SSRS: 3 X 3 ANOVA.

Measurement	Effect		*p*-value
Physical Stress	Main	Test Condition	0.108
	Main	Seat Position	0.692
	Interaction	Test Condition X Seat Position	0.947

* Indicates result is significant, †Indicates test was Bonferroni corrected, ‡Indicates test was Greenhouse-Geisser corrected

Table H-6.

Takeoff: 4 X 3 ANOVA.

Measurement	Effect		*p*-value
Bank Maintenance	Main‡	Test Condition	0.001*
	Pairwise Comparison†	Training – Pad	0.001*
	Pairwise Comparison†	Training – Unobstructed	0.017*
	Pairwise Comparison†	Training – Obstructed	0.001*
	Pairwise Comparison†	Pad – Unobstructed	1.000
	Pairwise Comparison†	Pad – Obstructed	1.000
	Pairwise Comparison†	Obstructed – Unobstructed	0.756
	Main	Seat Position	0.497
	Interaction‡	Test Condition X Seat Position	0.937
Heading Maintenance	Main‡	Test Condition	0.021*
	Pairwise Comparison†	Training – Pad	0.033*
	Pairwise Comparison†	Training – Unobstructed	0.007*
	Pairwise Comparison†	Training – Obstructed	0.022*
	Pairwise Comparison†	Pad – Unobstructed	1.000
	Pairwise Comparison†	Pad – Obstructed	1.000
	Pairwise Comparison†	Obstructed – Unobstructed	1.000
	Main	Seat Position	0.847
	Interaction‡	Test Condition X Seat Position	0.729
Climb Rate	Main‡	Flight Condition	0.060
	Main	Seat Position	0.425
	Interaction‡	Test Condition X Seat Position	0.571

* Indicates result is significant, †Indicates test was Bonferroni corrected, ‡Indicates test was Greenhouse-Geisser corrected

Table H-7.

Takeoff: 2 X 2 X 3 ANOVA.

Measurement	Effect		*p*-value
Bank Maintenance	Main	Flight Condition	0.128
	Main	Flight Mode	0.568
	Main	Seat Position	0.795
	Interaction	Flight Condition X Flight Mode	0.349
	Interaction	Flight Condition X Seat Position	0.833
	Interaction	Flight Mode X Seat Position	0.856
	Interaction	Flight Condition X Flight Mode X Seat Position	0.296
Heading Maintenance	Main	Flight Condition	0.390
	Main	Flight Mode	0.723
	Main	Seat Position	0.580
	Interaction	Flight Condition X Flight Mode	0.757
	Interaction	Flight Condition X Seat Position	0.846
	Interaction	Flight Mode X Seat Position	0.483
	Interaction	Flight Condition X Flight Mode X Seat Position	0.079
Climb Rate	Main	Flight Condition	0.897
	Main	Flight Mode	0.742
	Main	Seat Position	0.488
	Interaction	Flight Condition X Flight Mode	0.137
	Interaction	Flight Condition X Seat Position	0.624
	Interaction	Flight Mode X Seat Position	0.059
	Interaction	Flight Condition X Flight Mode X Seat Position	0.894

* Indicates result is significant, †Indicates test was Bonferroni corrected, ‡Indicates test was Greenhouse-Geisser corrected

Table H-8.

Turn Performance: 4 X 3 ANOVA.

Measurement	Effect		*p*-value
Altitude Maintenance	Main‡	Test Condition	0.288
	Main	Seat Position	0.496
	Interaction‡	Test Condition X Seat Position	0.995
Bank Maintenance	Main‡	Test Condition	0.541
	Main	Seat Position	0.304
	Interaction‡	Test Condition X Seat Position	0.940

* Indicates result is significant, †Indicates test was Bonferroni corrected, ‡Indicates test was Greenhouse-Geisser corrected

Table H-9.

Turn Performance: 2 X 2 X 3 ANOVA.

Measurement	Effect		*p*-value
Altitude Maintenance	Main	Flight Condition	0.185
	Main	Flight Mode	0.807
	Main	Seat Position	0.509
	Interaction	Flight Condition X Flight Mode	0.890
	Interaction	Flight Condition X Seat Position	0.915
	Interaction	Flight Mode X Seat Position	0.468
	Interaction	Flight Condition X Flight Mode X Seat Position	0.600
Bank Maintenance	Main	Flight Condition	0.168
	Main	Flight Mode	0.643
	Main	Seat Position	0.284
	Interaction	Flight Condition X Flight Mode	0.245
	Interaction	Flight Condition X Seat Position	0.926
	Interaction	Flight Mode X Seat Position	0.709
	Interaction	Flight Condition X Flight Mode X Seat Position	0.119

* Indicates result is significant, †Indicates test was Bonferroni corrected, ‡Indicates test was Greenhouse-Geisser corrected

Table H-10.

Level Flight: 4 X 3 ANOVA.

Measurement	Effect		*p*-value
Altitude Maintenance	Main‡	Test Condition	0.247
	Main	Seat Position	0.380
	Interaction‡	Test Condition X Seat Position	0.954
Heading Maintenance	Main	Test Condition	0.327
	Main	Seat Position	0.894
	Interaction	Test Condition X Seat Position	0.198

* Indicates result is significant, †Indicates test was Bonferroni corrected, ‡Indicates test was Greenhouse-Geisser corrected

Table H-11.

Level Flight: 2 X 2 X 3 ANOVA.

Measurement	Effect		*p*-value
Altitude Maintenance	Main	Flight Condition	0.158
	Main	Flight Mode	0.884
	Main	Seat Position	0.416
	Interaction	Flight Condition X Flight Mode	0.585
	Interaction	Flight Condition X Seat Position	0.875
	Interaction	Flight Mode X Seat Position	0.485
	Interaction	Flight Condition X Flight Mode X Seat Position	0.602
Heading Maintenance	Main	Flight Condition	0.307
	Main	Flight Mode	0.536
	Main	Seat Position	0.141
	Interaction	Flight Condition X Flight Mode	0.255
	Interaction	Flight Condition X Seat Position	0.638
	Interaction	Flight Mode X Seat Position	0.181
	Interaction	Flight Condition X Flight Mode X Seat Position	0.278

* Indicates result is significant, †Indicates test was Bonferroni corrected, ‡Indicates test was Greenhouse-Geisser corrected

Appendix. I.

Post-flight questionnaire descriptive results.

How much did you enjoy your helicopter ride today?

Flight Session	Seat	not at all	not so much	was okay	liked it	enjoyed it
Pad	Back	0 (0%)	2 (16.7%)	6 (50%)	3 (25%)	1 (8.3%)
	Front	1 (4.8%)	1 (4.8%)	10 (47.6%)	4 (19%)	5 (23.8%)
	Side	0 (0%)	2 (16.7%)	6 (50%)	2 (16.7%)	2 (16.7%)
Unobstructed	Back	0 (0%)	1 (8.3%)	0 (0%)	7 (58.3%)	4 (33.3%)
	Front	1 (4.8%)	0 (0%)	1 (4.8%)	5 (23.8%)	14 (66.7%)
	Side	0 (0%)	0 (0%)	2 (16.7%)	2 (16.7%)	8 (66.7%)
Obstructed	Back	0 (0%)	1 (8.3%)	5 (41.7%)	2 (16.7%)	4 (33.3%)
	Front	1 (4.8%)	2 (9.5%)	5 (23.8%)	6 (28.6%)	7 (33.3%)
	Side	1 (8.3%)	2 (16.7%)	1 (8.3%)	3 (25%)	5 (41.7%)

How much did you eat at your last meal before takeoff?

Flight Session	Seat	nothing	few	medium	regular	much
Pad	Back	2 (16.7%)	6 (50%)	3 (25%)	1 (8.3%)	0 (0%)
	Front	2 (9.5%)	7 (33.3%)	7 (33.3%)	5 (23.8%)	0 (0%)
	Side	3 (25%)	6 (50%)	3 (25%)	0 (0%)	0 (0%)
Unobstructed	Back	0 (0%)	7 (58.3%)	3 (25%)	2 (16.7%)	0 (0%)
	Front	0 (0%)	7 (33.3%)	7 (33.3%)	6 (28.6%)	1 (4.8%)
	Side	1 (8.3%)	5 (41.7%)	5 (41.7%)	1 (8.3%)	0 (0%)
Obstructed	Back	0 (0%)	1 (8.3%)	6 (50%)	4 (33.3%)	1 (8.3%)
	Front	0 (0%)	3 (14.3%)	8 (38.1%)	9 (42.9%)	1 (4.8%)
	Side	0 (0%)	1 (8.3%)	6 (50%)	4 (33.3%)	1 (8.3%)

How long ago was your last meal before takeoff?

Flight Session	Seat	< 1 hour	1 – 2 hours	2 – 4 hours	4 – 6 hours	> 6 hours
Pad	Back	0 (0%)	5 (41.7%)	5 (41.7%)	0 (0%)	2 (16.7%)
	Front	2 (9.5%)	7 (33.3%)	9 (42.9%)	1 (4.8%)	2 (9.5%)
	Side	2 (16.7%)	2 (16.7%)	5 (41.7%)	0 (0%)	3 (25%)
Unobstructed	Back	2 (16.7%)	2 (16.7%)	7 (58.3%)	1 (8.3%)	0 (0%)
	Front	1 (4.8%)	8 (38.1%)	9 (42.9%)	2 (9.5%)	1 (4.8%)
	Side	2 (16.7%)	0 (0%)	5 (41.7%)	3 (25%)	2 (16.7%)
Obstructed	Back	0 (0%)	11 (91.7%)	1 (8.3%)	0 (0%)	0 (0%)
	Front	1 (4.8%)	17 (81%)	2 (9.5%)	1 (4.8%)	0 (0%)
	Side	0 (0%)	10 (83.3%)	1 (8.3%)	0 (0%)	1 (8.3%)

How much did you drink during the last 3 hours prior to takeoff?

Flight Session	Seat	nothing	few	medium	regular	much
Pad	Back	3 (25%)	7 (58.3%)	1 (8.3%)	1 (8.3%)	0 (0%)
	Front	1 (4.8%)	9 (42.9%)	6 (28.6%)	5 (23.8%)	0 (0%)
	Side	3 (25%)	5 (41.7%)	4 (33.3%)	0 (0%)	0 (0%)
Unobstructed	Back	1 (8.3%)	5 (41.7%)	2 (16.7%)	4 (33.3%)	0 (0%)
	Front	0 (0%)	8 (38.1%)	6 (28.6%)	7 (33.3%)	0 (0%)
	Side	1 (8.3%)	7 (58.3%)	4 (33.3%)	0 (0%)	0 (0%)
Obstructed	Back	0 (0%)	3 (25%)	4 (33.3%)	5 (41.7%)	0 (0%)
	Front	0 (0%)	6 (28.6%)	8 (38.1%)	7 (33.3%)	0 (0%)
	Side	0 (0%)	3 (25%)	5 (41.7%)	3 (25%)	1 (8.3%)

When did you drink your last alcoholic beverage before takeoff?

Flight Session	Seat	< 6 hours	6 – 12 hours	12 – 18 hours	18 – 24 hours	> 24 hours
Pad	Back	0 (0%)	2 (16.7%)	2 (16.7%)	1 (8.3%)	7 (58.3%)
	Front	0 (0%)	0 (0%)	1 (4.8%)	1 (4.8%)	19 (90.5%)
	Side	0 (0%)	0 (0%)	2 (16.7%)	1 (8.3%)	9 (75%)
Unobstructed	Back	0 (0%)	0 (0%)	6 (50%)	0 (0%)	6 (50%)
	Front	0 (0%)	0 (0%)	3 (14.3%)	1 (4.8%)	17 (81%)
	Side	0 (0%)	0 (0%)	1 (8.3%)	1 (8.3%	10 (83.3%)
Obstructed	Back	0 (0%)	0 (0%)	4 (33.3%)	1 (8.3%)	7 (58.3%)
	Front	0 (0%)	0 (0%)	0 (0%)	2 (9.5%)	19 (90.5%)
	Side	0 (0%)	0 (0%)	1 (8.3%)	1 (8.3%)	10 (83.3%)

Have you been distracted by the outside world view (through the helicopters' windows)?

Flight Session	Seat	not at all	not so much	quite a bit	was distracted	very much
Pad	Back	8 (66.7%)	2 (16.7%)	2 (16.7%)	0 (0%)	0 (0%)
	Front	15 (71.4%)	5 (23.8%)	1 (4.8%)	0 (0%)	0 (0%)
	Side	8 (66.7%)	3 (25%)	1 (8.3%)	0 (0%)	0 (0%)
Unobstructed	Back	1 (8.3%)	9 (75%)	0 (0%)	2 (16.7%)	0 (0%)
	Front	3 (14.3%)	12 (57.1%)	2 (9.5%)	3 (14.3%)	1 (4.8%)
	Side	1 (8.3%)	8 (66.7%)	3 (25%)	0 (0%)	0 (0%)
Obstructed	Back	10 (83.3%)	2 (16.7%)	0 (0%)	0 (0%)	0 (0%)
	Front	19 (90.5%)	2 (9.5%)	0 (0%)	0 (0%)	0 (0%)
	Side	12 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)

Compared to taking the given task in a calm, non-moving office environment, how much do you think that performing the task in the helicopter impaired your performance?

Flight Session	Seat	not at all	not so much	quite a bit	definitely	very much
Pad	Back	3 (25%)	6 (50%)	2 (16.7%)	1 (8.3%)	0 (0%)
	Front	7 (33.3%)	13 (61.9%)	1 (4.8%)	0 (0%)	0 (0%)
	Side	2 (16.7%)	9 (75%)	1 (8.3%)	0 (0%)	0 (0%)
Unobstructed	Back	2 (16.7%)	3 (25%)	5 (41.7%)	1 (8.3%)	1 (8.3%)
	Front	0 (0%)	10 (47.6%)	7 (33.3%)	2 (9.5%)	2 (9.5%)
	Side	0 (0%)	7 (58.3%)	3 (25%)	1 (8.3%)	1 (8.3%)
Obstructed	Back	1 (8.3%)	5 (41.7%)	2 (16.7%)	4 (33.3%)	0 (0%)
	Front	1 (4.8%)	10 (47.6%	5 (23.8%)	2 (9.5%)	3 (14.3%)
	Side	0 (0%)	7 (58.3%)	1 (8.3%)	2 (16.7%)	2 (16.7%)

Numbers represent the total amount of responses while parentheses represent the percentage of responses within each group.

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